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# ORIGINAL ARTICLES.

## Some Problems of Classification in the Canadian Pre-Cambrian Shield.[1]

By M. E. Wilson.

### Introduction.

GEOLOGICAL investigation in the Canadian Pre-Cambrian Shield up to the present, except for exploratory excursions, has been confined almost entirely to the territory along its southern border, most of which is included in the basin of the Great Lakes and the St. Lawrence River; and all classifications that have been proposed for the rocks of the Shield, have had reference chiefly to the formations occurring in this region. But as detailed geological studies are carried farther and farther north, the major divisions of the Pre-Cambrian used in the St. Lawrence province will be extended to the whole Canadian Shield. It is important, therefore, that the classification adopted for the Pre-Cambrian formations of the St. Lawrence province be equally applicable to all of this vast area.

The problems of classification that are of immdeiate interest to Canadian geologists working in the Pre-Cambrian, however, are those that have arisen within the St. Lawrence province. This region is divided into four geographically separate geological sub-provinces, in each of which the succession of formations is so different that few positive correlations either of formations or unconformities in different sub-provinces can be made. These sub-provinces are: (1) the region lying along the southern border of the Laurentian highlands in south-eastern Ontario and Quebec, the Grenville sub-province; (2) the region extending north-east from Lake Superior and Lake Huron to Lake Timiskaming, the Timiskaming sub-province; (3) the region north-west of Lake Superior, the north-west sub-province; and (4) the region south of Lake Superior, in the United States, the southern sub-province. Between the Grenville and the Timiskaming sub-provinces there intervenes an extensive belt composed chiefly of banded gneisses; between the Timiskaming sub-province and the two western sub-provinces there is a vast area underlain chiefly by granite to the north of Lake Superior and overlapping Palaeozoics to the south; and between the regions north-west and south of Lake Superior lies Lake Superior and a broad belt of late Pre-Cambrian sediments that hide the earlier formations.

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[1] Published with the permission of the Director of the Geological Survey of Canada.

The problems of classification in the St. Lawrence province are chiefly, therefore, the problems of correlation between the different sub-provinces. As a starting point in stating these problems, it will be assumed that only those observations or inferences from observations regarding which there is entire agreement among geologists familiar with the St. Lawrence region, are established. If this procedure be adopted it is found that there are two important problems or groups of problems in classification in the St. Lawrence province that await solutions.

## STATEMENT OF PROBLEMS.

The data essential to Pre-Cambrian classification in the St. Lawrence province and regarding which there is probably complete agreement among geologists familiar with this region are :—

(1) That in the Timiskaming sub-province there is a pre-Huronian palaeoplain, above which the rocks, except in the southern part, are only slightly disturbed, and below which there is a basal complex; and

(2) That there is a similar palaeoplain in the region south of Lake Superior that may be correlated with the pre-Huronian palaeoplain of the Timiskaming sub-province.

The last correlation was discussed in detail by R. D. Irving[1] in 1887, has been accepted by geologists engaged in Pre-Cambrian field work in the region south of Lake Superior, and, so far as known to the writer, has not been questioned by other geologists. If this correlation is established, then in Pre-Cambrian time a pre-Huronian palaeoplain extended for nearly 1,000 miles across the southern border of the Canadian Shield. It is this palaeoplain, first recognized by Logan, that forms the starting point in all Pre-Cambrian classifications in the St. Lawrence province.

*The pre-Huronian palaeoplain in the north-west and Grenville sub-provinces.*—The first major problem in classification that presents itself is the position of the pre-Huronian palaeoplain in the geological succession of the region north-west of Lake Superior and of the Grenville sub-province.

In the region north-west of Lake Superior there is a palaeoplain at the base of the Animikie, the Eparchaean interval of Lawson,

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[1] *Amer. Journal of Science*, vol. xxxiv, 1887, pp. 204–6, 249–63, 365–74.

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| Late Pre-Cambrian<br>(Huronian of Logan) | Keweenawan series—<br>Conglomerate, sandstone, etc., lavas, dykes and sills of diabase.<br>Animikie series—<br>Conglomerate, iron formation, and slate. | Olivine diabase.<br>Killarney granite.<br>Dykes and sills of diabase and norite, conglomerate, and sandstone.<br>Whitewater series—<br>Conglomerate, tuff, slate, and sandstone. | Diabase dykes. | Grenville and Rigaud stocks of granite, and syenite.<br>Diabase dykes.<br>Lamprophyre mass and dyke. |
| | Granite<br>(Algoman of Lawson)<br>Lamprophyre, gabbro, etc.<br>Seine, Steeprock series, etc.[1] [2] | Cobalt series—<br>Conglomerate argillite, greywacke, quartzite, and limestone.<br>Bruce series—<br>Conglomerate, quartzite, limestone, and indurated silt. | | |
| Early Pre-Cambrian<br>(Laurentian of Logan) | Granite<br>(Algoman of Lawson)<br>Lamprophyre, gabbro, etc.<br>Seine, Steeprock series, etc.[1] [2] | Granite, syenite, etc.<br>Lamprophyre dykes. | Granite, syenite, etc.<br>Gabbro, diorite. | Granite, syenite, etc.<br>Buckingham series (igneous).<br>Peridotite, gabbro, anorthosite (including Morin mass), syenite, etc. |
| | Granite, etc.<br>Gabbro, anorthosite, etc. | Complex of sediments, and volcanics. | Hastings series—<br>Conglomerate, argillite, and limestone. | Grenville or Grenville-Hastings Series—<br>Limestone, quartzite, and sillimanite-garnet gneiss. |
| | Complex of sediments and volcanics, including the Keewatin, Couchiching, Rice Lake series, etc. | Sediments :<br>Timiskaming series,<br>Dore series,<br>Pontiac series, etc.,<br>Iron formation.<br>Volcanics :<br>Abitibi volcanics, pre-Huronian schist complex, or Keewatin of some reports. | Grenville series—<br>Acid and basic lavas,<br>Mica schist, quartzite, and limestone. | |

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[1] Classified as Huronian and hence late Pre-Cambrian by A. C. Lawson and United States Geologists.

[2] Relationship to formations of other sub provinces in doubt.

but in the complex beneath this palaeoplain there are sediments resting unconformably on granite that are intruded by granite (Algoman), indicating that an older erosion interval of considerable importance is also present. Some Canadian geologists, impressed with the similarity of the Vermilion, Steeprock, and other sediments of pre-Animikie age to the pre-Huronian (Timiskaming, etc.) sediments of the Timiskaming region, have assumed that the pre-Animikie and the pre-Huronian palaeoplains are the same.[1] A. C. Lawson [2] and the United States geologists familiar with the geology of the Lake Superior region, on the other hand, as shown in the tables of formations (p. 3), classify the pre-Algoman sediments (Vermilion Lake series, Steeprock series, etc.) as Huronian and regard the older unconformity as the pre-Huronian palaeoplain. These alternative possibilities constitute the most difficult and, as later discussion will show, perhaps the most important problem in the classification of the Canadian Pre-Cambrian.

It has generally been assumed that in the Grenville sub-province the Huronian sediments are not represented and that the basal complex of this region (Laurentian of Logan) is pre-Huronian in age, but recently it has been suggested by W. H. Collins [3] and by T. T. Quirke [4] from studies in the region north-east of Lake Huron that the Grenville series may be Huronian and that the granite batholiths that intrude the Grenville series are (Killarney) post-Keweenawan in age. It is probable that most Pre-Cambrian geologists will hesitate to accept this suggestion until it is established, but so long as the relationships in this region are not fully determined, the position of the pre-Huronian palaeoplain in the Grenville sub-province remains a problem.

*Dual versus triple classification.*—The second major problem in classification has reference to the divisibility of the pre-Huronian complex. Is this complex divided into two parts by a palaeoplain similar to that at the base of the Huronian ? and if this palaeoplain exists, can it be used for the classification of the pre-Huronian into two divisions ? In other words, should the Pre-Cambrian of the Canadian Shield be divided into two or three major divisions ?

In the Timiskaming sub-province there are belts of clastic sediments (Timiskaming, etc.), some of which at least appear to rest unconformably on older Abitibi (Keewatin) volcanics. The presence of granite pebbles in the conglomerate members of these sedimentary groups indicates that granite was undergoing erosion somewhere within or near the Timiskaming belt where these sediments were laid down, but whether this granite is older or younger than the volcanics of the complex or whether the surface upon which these sediments were deposited was a palaeoplain is unknown.

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[1] Miller, W. G., and Knight, C. W., *Journal of Geology*, vol. xxiii, pp. 585–99, 1915. Miller, W. G., Geol. Mag., Vol. VI, 1919, pp. 524–6.

[2] *University of California, Bull. Dept. of Geology*, vol. x, pp. 1–19.

[3] *Memoir* 143, *Geol. Surv. Can.*, 1925, pp. 102–3.

[4] *American Journal of Science*, vol. vi, pp. 165–73.

In the sub-province north-west of Lake Superior there is an unconformity in the pre-Animikie complex which, as previously explained, has been correlated by some geologists with the pre-Huronian unconformity and by others with the (pre-Timiskaming, etc.) unconformity believed to exist within the pre-Huronian complex of the Timiskaming sub-province. According to the former correlation the Algoman granite was intruded in the midst of the Huronian; according to the latter it is pre-Huronian.

In the Grenville sub-province the Grenville series is overlain unconformably throughout a restricted area in south-eastern Ontario by the Hastings series. The writer has recently completed an examination of this region and has concluded that the Grenville series was neither disturbed nor intruded by granite prior to the deposition of the Hastings series, and that the unconformity that separates the two series is not of great importance. If the Grenville and Hastings series were Huronian, as suggested by Quirke, this unconformity would then in any case have no significance so far as the subdivision of the pre-Huronian is concerned. If they are pre-Huronian and the writer's conclusions are correct, the unconformity is local and not part of a palaeoplain.

In the region south of Lake Superior the area of rocks mapped as pre-Huronian is relatively small, and, so far as known to the writer, the subdivision of the pre-Huronian of that region has never been proposed.

## DISCUSSION.

The preceding statement of the problems of classification in the Pre-Cambrian of the St. Lawrence province indicates clearly that the important problem so far as classification is concerned is the second, that is whether a dual or triple classification will most adequately serve to present the succession of events in the geological history of this region; and the first problem, the position of the pre-Huronian palaeoplain in the sub-province north-west of Lake Superior and in the Grenville sub-province, is of importance chiefly because of its bearing on the second. It is also clearly evident that the basis for the triple classification, the existence of a second palaeoplain or extended erosion surface within the pre-Huronian complex, is as yet a hypothesis which may require many years of detailed field work to be established or disproved. In the Timiskaming sub-province the difficulties are especially formidable because the basal complex consists largely of volcanics, and because it is largely covered by late Pre-Cambrian rocks in the southern part of the belt and by lacustrine deposits in the north. There is another aspect of the problem, however. Whatever classification is adopted for the St. Lawrence basin will eventually be applied to the whole Canadian Shield and should therefore be equally applicable to the whole of this vast region. If it is proving so difficult to correlate the different formations and unconformities in the St. Lawrence province will it not be much more difficult to make these correlations throughout the much larger area? It is probable, as detailed investigation within the Canadian Shield is continued, that remnants of older and older erosion surfaces will be discovered, and it does not seem practicable or advisable to create a new major division for each newly discovered unconformity. Even if the existence of an older erosion surface in the Timiskaming sub-province and in the sub-province north-west of Lake Superior be established, it is evident that throughout the greater part of the Shield this older surface has been destroyed. It may be more satisfactory, therefore, in any case to retain the dual classification for the major subdivisions of the Canadian Pre-Cambrian and use other unconformities both above and below the pre-Huronian palaeoplain for minor or local subdivisions.

## SUMMARY.

The region lying along the southern border of the Canadian Shield, the St. Lawrence basin, to which by far the greater part of the field work so far performed in this vast area has been confined, is divided into four geographically separate sub-provinces, in each of which the succession of formations is so different that few positive correlations of either formations or unconformities in different sub-provinces can be made. It is probable, however, that all geologists familiar with this region are agreed that there is a palaeoplain at the base of the Huronian that originally at least extended over the southern part of the Canadian Shield. If the existence of this palaeoplain be assumed as established then there are two major problems in Pre-Cambrian classification in this region that remain unsolved: (1) What is the position of the pre-Huronian palaeoplain in the succession of formations present in the sub-province north-west of Lake Superior and in the Grenville sub-province? and (2) is there a second erosion plain within the pre-Huronian complex, and, if so, can it be used satisfactorily for the classification of the pre-Huronian into two major divisions equivalent in rank to the Huronian?

The purpose of this paper has been to point out (1) that there is no present agreement regarding the solution of either of these problems; (2) that the existence of a widespread unconformity within the pre-Huronian complex of the St. Lawrence province is, as yet, only a hypothesis, and (3) that there are only two logical courses to be followed in the classification of the Pre-Cambrian formations of the Canadian Shield, either to adopt the dual classification or to use it tentatively in the manner indicated in the accompanying table, until the existence of the second widespread unconformity is established or disproved. It may be suggested, however, that since considerable difficulty is being encountered in applying the dual classification even within the St. Lawrence province, it may be more practical to adopt the dual classification for the major divisions of the Pre-Cambrian notwithstanding the possible presence of an unconformity within the pre-Huronian complex.

In conclusion the writer wishes to express his indebtedness to his colleagues of the Geological Survey of Canada, W. H. Collins, F. J. Alcock, T. L. Tanton, and J. F. Wright, for criticism of the columns in the table of formations having reference to the different sub-provinces with which they are especially familiar.

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## Rhythmic Banding of Ferric Oxide in Silicified Rhyolite Tuffs.[1]

By H. L. Chhibber, M.Sc., F.G.S., F.R.G.S.

DURING the investigation of the geology of the old volcano of Mount Popa, Upper Burma, the writer picked up certain specimens of silicified tuffs, showing red and yellow rhythmic bands of iron oxide. A similar case of banding, but due to manganese dioxide, has been observed by Tarr.[2]

The specimens under description were found associated with silicified tuffs of the Kyaukpadaung area near Mount Popa, Myingyan district, Upper Burma. The tuffs belong to the close of the Tertiary period. Two good specimens P/279 and P/155 are preserved in the collections of University College, Rangoon. P/279 is from the tuff hill S.E. of Mongan village (N. Lat. 20° 42′ E. Long. 95° 18′ 15″) while P/155 was obtained from 1 mile south of Gwegon village (N. Lat. 20° 50′ 30″ E. Long. 95° 12′ 30″). The P/279 is whitish in colour, and is a piece of partially silicified tuff. The outer band measuring about one-third of an inch in thickness consists of white unsilicified tuff, while the inner portion is wholly silicified. The other specimen P/155 is of light purple colour. In P/279 the bands are bright red in colour, while they are yellow in P/155. In the former, the bands are eccentrically concentric (see Fig. 1), while in the latter they are elliptical.

In size each band varies from 1 to 3 mm. in thickness and in P/155, the elliptical central zone, has major and minor axes measuring 15 mm. and 5 mm. respectively. The thickness and the intensity of colour of the bands is not uniform.

In P/279, the diffused material forming the red bands has been determined to be ferric oxide, while in P/155, it appears that the yellow colour of the bands is due to limonite, the result of hydration of ferric oxide. Tarr[3] tried to show that the manganese dioxide in his specimens may either have been derived from the rhyolite tuff or may have come from without. In the present case the extraneous source of the iron oxides seems clear, since the material is also deposited as an incrustation in botryoidal aggregates or disseminated in the gas cavities of the more granular or pumiceous rock found elsewhere.

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[1] Read at the Indian Science Congress, Bombay, 1926, vide *Abstracts of Papers*.

[2] Tarr, W. A., " Rhythmic Banding of Manganese dioxide in Rhyolite Tuff," *Journ. Geology*, vol. xxvi, 1918, pp. 610–17.

[3] Op. cit.

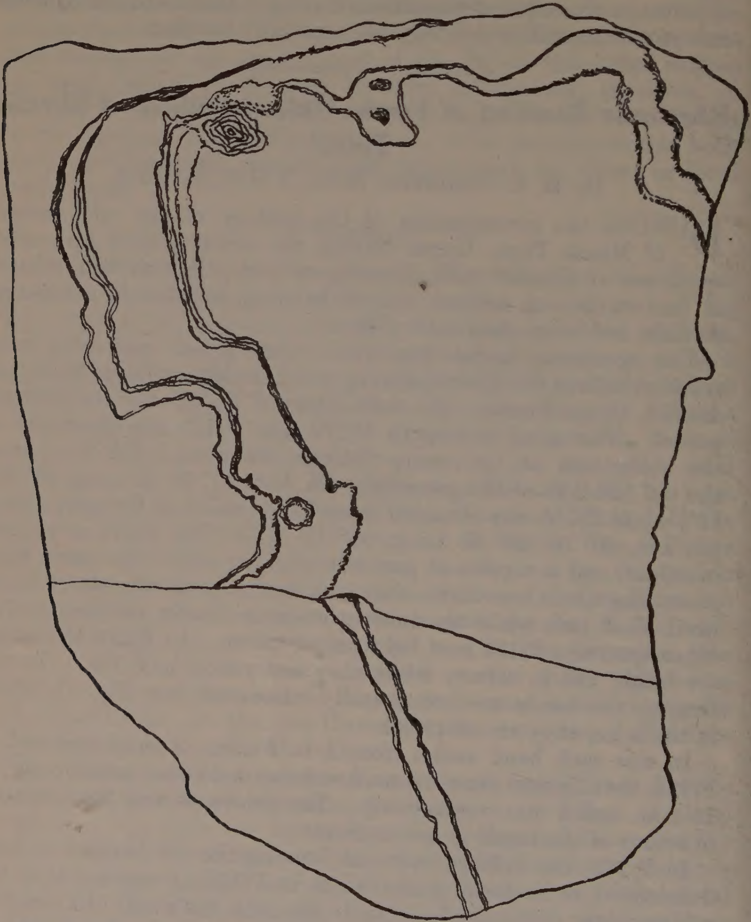

FIG. 1.—Bands of ferric oxide in silicified tuff, Mt. Popa, Upper Burma.

The origin of the ferruginous solutions is not difficult to explain. Either the thermal waters and heated vapours which brought about the silicification of these tuffs may have been the source of the iron oxide or the circulating waters may have leached out iron from the ferruginous concretions so profusely distributed in the neighbouring Irrawaddian Series. The latter seems more likely since the banding seems to have been produced subsequent to the silicification of the tuffs.

Under the microscope P/279 consists of crypto or micro-crystalline silica and is fine-grained and fairly homogenous. The texture does not alter where it is crossed by the coloured bands, therefore it is assumed that the coloured banding is superimposed. In other words the fine-grained tuff has acted as a medium for the production of the bands by circulating solutions. Slight variation in the texture would account for the irregularity in the coloured bands. In P/155 the texture is similar but the yellow coloured bands are shown by the microscope to be due to the concentration of granules of limonite. In fact, the whole rock owes its purple colour to microscopic grains of hematite which are distinctly visible under the microscope and the hydration is best observed on the surface. It is probable that the ferruginous solutions may have diffused in the siliceous gel; as remarked above, the thin sections are seen to consist of crypto- or micro-crystalline silica but it has been shown by Holmes[1] that gels are not essential for the development of Liesegang rings as he has demonstrated their formation in loosely packed flowers of sulphur. It is therefore suggested that these fine-grained porous tuffs behaved in the same way. It will be obvious that the bands must have been produced when the texture of the rock was as it is at present, i.e. after silicification, otherwise silicification would cross the banding irregularly. The writer has already suggested a similar origin of the ferruginous rhythmic banding so well seen in the " Older Lavas " described in the paper on " The Igneous and associated rocks of the Kabwet Area, Upper Burma ".[2] Here ferruginous solutions infiltrated into decomposed basaltic lava and produced similar coloured bands.

The phenomena observed in these tuffs are thus comparable with the well-known banding of agates by diffusion of ferruginous and other salts into the siliceous material.

The eccentric character of the bands, especially seen in P/279, may be due partly to the varying character of the rock, viz. density, porosity and composition, and partly to the varying supply of the diffusing solution. Tarr in the paper cited above, has rightly remarked that " unlike in laboratory experiments, where the rhythmic banding is produced in a gel of uniform composition and density, the rhythmic banding in nature would find varying factors on all sides and hence one should really expect the banded structure to vary from perfect rings ".

In conclusion, the writer wishes to thank Dr. L. Dudley Stamp for kindly reading the manuscript and for discussing the problem.

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[1] Holmes, H. N., "Rhythmic Banding": *Science*, new series, vol. xlvi, 1917, 422.

[2] Stamp, L. D., and Chhibber, H. L., *Trans. Min. and Geol. Inst. India*, vol. xx, 1925.

## SUMMARY.

A case is described of rhythmic banding by iron oxide in a rhyolitic tuff. The fine-grained tuff has acted as a medium for the production of Liesegang rings, the irregularity in the rings being ascribed to minute variations in the texture of the rock, naturally less homogeneous than a gel.

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# The Underground Structure of Eastern England.

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IN a previous paper in this Magazine, the writer dealt with the underground tectonics of the Southern Midlands of England,[1] with special reference to the importance of trend-lines having a general north-west to south-east (Charnoid) direction. In the course of the argument, when dealing with certain discontinuities in the Jurassic strata, the following sentence occurred (page 210): " These intra-Jurassic disturbances may be correlated with the Cimmerian phase of crust-disturbances in central Germany, in which in many areas a north-west to south-east directrix is dominant. The author hopes in a later publication to pursue this subject further." Since that time the whole matter has been investigated along the lines followed in the earlier paper, with special application to areas lying further to the east and north than those previously dealt with, and the following pages are an attempt to deal with the problem then suggested, namely, the possibility of accounting for certain hitherto neglected features of British stratigraphy by reference to a phase of crust-disturbance well known in north-western Europe, but as yet hardly recognized by British geologists.

During the last few years many very important investigations have been carried out in western Germany, Holland, and Belgium, largely with an economic application; the main objects were the discovery or development of the extension of workable coalfields into east and south Holland, and north-eastern Belgium, and of the German salt areas into Holland. The practical result of these investigations has been the discovery of coal at a workable depth in the Campine (north-eastern Belgium) and in Dutch Limburg, as well as of masses of potash salts in at least two localities in Dutch territory (Winterswijk and Buurse). By means of an intensive boring campaign a vast amount of information has been obtained as to the underground structure of the areas concerned and the age of the movements of the crust to which these structures are due. To put the matter into general terms the most striking features demonstrated are the dominance of north-west to south-east trend lines in the deep-seated structure of western Germany, Holland, and northern Belgium, and the occurrence of a notable phase of orogenic movement, of special and peculiar type, towards the end of Jurassic times (the Cimmerian phase of Stille). This phase reached its climax about the end of the Kimmeridgian or early Portlandian, which as is well known, was a period of altogether peculiar conditions in eastern and southern England, when the normal marine sequence of the Upper Jurassic underwent a serious interruption, leading to the formation in different areas of very variable and remarkable types of sediment, or even in certain localities, for example in Cambridgeshire, to a complete absence of deposition in latest Jurassic and earliest Cretaceous times. The fact that this local uplift and unconformity in England coincided with an important phase of crust-movement on the continent has as yet hardly received the recognition it deserves, although a great amount of attention has been focussed on the contemporaneous Speeton Clay facies in Yorkshire,[1] and the anomalous strata of the same age in Lincolnshire.

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[1] " On the Tectonics of the Southern Midlands ": GEOL. MAG., Vol. LXII, 1925, pp. 193–222.

In the earlier paper already mentioned, the continuation of the Charnian axis was traced by various lines of evidence in a south-easterly direction as far as Kent, and north-westwardly into the main Pennine axis; to the north-east of this line nothing was attempted, while to the west of it the evidence was fully discussed. This line will therefore serve as a western boundary to the area here to be considered in detail.

The present strike of the Upper Mesozoic rocks of southern and eastern England is obviously in the main of a middle Tertiary date, approximately Miocene. Thus from Dorsetshire to the Wash the general direction of the outcrop is south-west to north-east, in south Norfolk it begins to swing round to the north: in Lincolnshire it is more nearly north-west, while beyond the Humber the strike shows a good deal more variation: in the north of Yorkshire it is obviously controlled by the Cleveland anticline. In all this area from Dorset to the Yorkshire Wolds the line of contact of Jurassic and Cretaceous, whether conformable or not, is thus seen to be involved in Alpine crust-movements. There is no positive evidence to show when the last movement of the Cleveland axis occurred. In considering the effect of the earlier disturbances it is therefore necessary to eliminate the Tertiary element; in the whole region north of the Thames at any rate this is not difficult; for the most part the effects are so small as to be almost negligible, which of course is by no means the case in the south of England.

It is unnecessary to repeat the arguments set forth in earlier publications as to the intimate connexion which is believed to exist between the Charnian axis itself, together with other axes of similar trend, and the unconformable relations of the Jurassic and Cretaceous systems in the eastern Midlands, the local discontinuity of the Cambridge Greensand, and other features. It will be here assumed that all this is established: the object of the present paper is to extend similar ideas to the stratigraphy of the east of England, including Lincolnshire and Yorkshire, and to link up the whole of the facts thus ascertained with the conclusions of the German, Dutch, and Belgian geologists as to the area on the other side of the North Sea.

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[1] G. W. Lamplugh, *Proc. Yorks Geol. Soc.*, vol. xx, 1923–4, p. 1, with bibliography.

The chief lines of evidence available for this investigation are the outcrops of the Mesozoic rocks in eastern England and the results of deep borings in the south-east of England, in France, Belgium, and Holland, together with such surface indications as are to be found in the later rocks. The literature of continental geology bearing on this point is enormous in volume and increasing at a very rapid rate, many important memoirs having been presented at the meeting of the International Geological Congress at Brussels in 1922. Much valuable material is also contained in reports on the development of the Kent coalfield, and doubtless much more exists in an unpublished form, unfortunately as yet inaccessible to geologists. It might seem at first sight that all this has not much bearing on the point at issue, the underground geology of East Anglia, but it is hoped to show in the course of this discussion that there is a close connexion. At the risk of appearing discursive, a little space must first be devoted to a consideration of some points of continental geology.

## I. The Trend-lines of North-West Europe.

It is now universally recognized that the most important features in the distribution of the Palaeozoic rocks of north-western Europe are due to the occurrence of two sets of major earth-movements, the Caledonian with a dominant north-east to south-west strike, of late Silurian, or early Devonian date, and the Armorican or Hercynian system, of late Carboniferous and post-Carboniferous age, the last-named set being mainly responsible for the present distribution of the coal-basins.[1] Here unfortunately we come up against a confusion of nomenclature. It is hardly necessary or desirable to discuss the whole tangled question in detail; it must suffice to say that in this paper the various terms are used in the following somewhat dogmatic senses. *Armorican* is taken to mean trend-lines starting from somewhere in the interior of France and running first in a general north-west direction, with a gradual bending to west-north-west and due west, and a final tendency (in Ireland) to a west-south-west direction. In a similar way the *Variscan* fold-lines tend from central France north-easterly and finally easterly in central Germany. The term Hercynian is avoided owing to ambiguity, because in Germany it is often taken to mean a north-west to south-east trend[1]; in fact what in England we understand by Charnian, whereas in English geological literature it is often used to express the sum total of the Carboniferous-Permian fold-system (Armorican + Variscan) irrespective of trend. The term Charnian or Charnoid, as here used, invariably indicates structures, whether folds or faults, having an approximately north-west to south-east trend.

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[1] For a classification of the fold-systems and resulting structures see Stainier, *Trans. Inst. Min. Eng.*, vol. li, 1916, pp. 101–4 and p. 122.

On the continent the northern limit of this folded area, with its two dominant directions, is constituted by the coal-basins of southern and south-eastern Belgium and northern France, a region of extraordinary complexity, whose correct interpretation is of first-class importance for an understanding of the underground geology of southern and eastern England. From what has been already said, it will be clear that the change-over from the Armorican to the Variscan trend-lines must take place somewhere within this Franco-Belgian coal-belt, and it is the Armorican trend-line that is of chief importance for our present purpose.

When regarded in the most general terms, Belgium is seen to consist of a mass of Lower Palaeozoic and perhaps older rocks, the massif of Brabant, whose present disposition is to be referred to the Caledonian fold-system, over-ridden from the south and south-east by later overthrust masses of Devonian and Carboniferous strata. The plateau of Brabant acted as a horst, and against it the advancing earth-waves of the Armorican-Variscan system broke and expressed themselves as a series of folds and overthrusts: the synclinal of Namur; the anticlinal of the Condroz; the synclinal of Dinant; and still other folds, as partially revealed by the "window" of Theux; the folds of the Ardennes and so forth. These constituted a mountain chain of Alpine type, now mostly levelled down, so that a large part of the Belgian coalfield now forms an area nearly as flat as the Fens of East Anglia. Nevertheless the structures are there, underground, below a thin covering of Mesozoic and Tertiary rocks. Though intensely complicated in detail, all of this is simple in its main lines.

We now come to a point of the utmost importance in the argument; namely, that to the east and north of the plateau of Brabant, in the Campine, in south Holland and in western Germany, the intensive boring campaign there carried on has revealed a structure of an entirely different character. The Palaeozoic floor of this region consists essentially of a series of horsts and rift-valleys, which have a dominant north-west to south-east strike. This is brought out with the utmost clearness in the admirable map published by Dr. W. A. J. M. van Waterschoot van der Gracht.[2] From this map it is clearly apparent that the whole of this region is underlain at a great depth by Carboniferous strata, having on the whole a general dip to the north-west, and traversed by a great series of north-west to south-east dislocations, such that the Coal-measures are reached at workable depths only in the horsts, whereas in the rift-valleys (slenks) they are too deep to be worked.

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[1] This usage in point of fact has the right of priority.

[2] W. A. J. M. van Waterschoot van der Gracht, "Proeve eener Tektonische Schetskaart van het Belgisch-Nederlandsch-Westfaalsche Kolenveld en het aangrenzende noordelijke Gebied tot aan de breedte van Amsterdam": *Jaarverslag der Rijksopsporing van Delfstoffen over* 1913, Amsterdam, 1913.

Before, however, this point is taken up in detail, it will be well to consider briefly certain analogies that exist in the geological structures of eastern England and the neighbouring parts of the continent. As seen on the map the structure of the Boulonnais at once suggests itself as the obvious continuation of the Wealden dome. There is, however, also the important point that Upper Palaeozoic rocks actually come to the surface in the Boulonnais (e.g. the Devonian at Marquise, etc.), whereas in England they are usually at about — 1000 ft. O.D.[1] It is unnecessary to repeat here the arguments on which the existence of the Kent coalfield was postulated and subsequently proved by boring. It is certain that this coalfield is a structure analogous to the coal basins of Belgium and northern France, of Radstock and of South Wales, lying on the northern side of an important anticlinal Armorican fold-line; it is still a matter of some discussion as to which of the axes in northern France (Artois and Pas de Calais) is to be correlated with the Mendip-Pembroke anticline and the relation to the Belgian coal-basins is complicated by the change from the Armorican to the Variscan trend somewhere in France. The most obvious and simple correlation is to regard the Mendip-Pembroke anticlinal fold as the continuation of the Eifel-Condroz-Faille du Midi line, and on this point a short study of the relation of certain Belgian tectonic features to those of southern England may throw some light.

## II. The Plateau of London and Brabant.

The plateau of Brabant has already been mentioned as the chief element in the structure of northern and central Belgium; it consists of Lower Palaeozoic rocks of the usual type, ranging from Cambrian to Silurian, exposed in river valleys in certain areas south of Brussels, and known from innumerable borings to underlie the northern part of the country at a very small depth. On the south side Devonian strata come in, apparently with a break at the base, lower Devonian being absent; whether this is due to overlap or disturbance does not seem to be quite clear. The southern boundary of the Plateau of Brabant runs more or less east and west from probably somewhere near Tournai to a little east of Namur, where it turns suddenly to east-north-east, and finally north to Maastricht. From this point it sinks under the buried coalfield of the Campine to a great depth, and becomes involved in the Saxonian fractured area.

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[1] The smallest depths recorded are – 527 feet at Culford, and – 150 feet at Calvert.

Now the point here sought to be made is that there is a close analogy between the plateau of Brabant and the Palaeozoic plateau of south-eastern England. It is necessary therefore here to say a few words as to our present knowledge of the structure of the last-named, which of course can only be reached by deep borings, and these are not numerous over large parts of the area. At any rate we know that there are Lower Palaeozoic or older rocks under Suffolk and Essex (Lowestoft, Culford, Weeley, Stutton, Harwich, Beckton, Ware, Fobbing) and in Kent (Cliffe, Chilham) with Devonian around London. The occurrence of Cambrian rocks in Buckinghamshire (Calvert) at only — 150 O.D. is also notable, and is very like the relations in Brabant. The general impression given by a consideration of these facts is that the South Eastern Plateau consists of older rocks to east and north, with Devonian to west and south, and therefore to some extent forms a mirror-image as it were of the Plateau of Brabant. On this idea the coalfields of the English Midlands should be regarded as analogues of the Campine; this analogy holds in a general way, but in England the pre-existence of well-marked Charnian fold-structures has introduced further complications.

Now it is important to remember that the plateau of Brabant is bounded on the south by the intensely folded and overthrust zone of the Belgian coal-basins, and it remains to consider whether anything of the kind exists in southern England. In the first place it is well known that very considerable disturbances exist in the Pembrokeshire coalfield, which is a long way off, and in the Radstock coalfield, which is not much more than 100 miles west of London. Here we find ample evidence of overthrusting, in the inverted strata south of Radstock, the Vobster outlier, the Farmborough fault and the reversed faults of the Kingswood anticline, besides many other minor structures which have not yet been worked out in detail. The existence of inversions in this area was clearly recognized by Buckland and Conybeare as early as 1824.[1] It is therefore highly probable that similar relations hold in the area intervening between Somerset and northern France; in fact it would be unnatural if such were not the case.

Nevertheless it must be admitted that the facts available as to the lie of the rocks in the Kent coalfield lend very little support to the idea here suggested. The author has not had access to any unpublished information on this area, and has no inside knowledge of it, but all the published descriptions certainly suggest flat-lying strata. However, it appears that few or none of the boreholes have been surveyed and the figures given as to dips in them are quite unreliable, owing to uncertainty as to their verticality. It is only in shafts that the figures can be accepted without doubt, and in these the dips indicated are very small and variable. But certain lines of evidence converge to indicate that the structures are not quite so simple as would at first appear; one of the most important considerations is the very great differences in the succession as revealed in borings separated only by short distances, and the consequent difficulty of correlating the seams. In the discussion on a paper by the late Dr. Arber, it was suggested by Professor H. Louis that very flat-lying dislocations might account for some of the discrepancies observed, and this seems very plausible. At any rate the possibility is recognized, although there is no direct published evidence so far as the author is aware. Dr. Arber himself suggested on one occasion that in certain borings in Kent the sequence of seams appeared to be repeated. It is known that in Belgium the fold-axes undulate in an east and west direction, and it is of course possible that the Kent coalfield is an area of super-elevation of this kind, where everything has been removed by denudation in pre-Jurassic times, except the lowest-lying autochthonous coal-deposit. At any rate is is difficult to believe that the structure of the Kent coalfield is as simple as it appears to be, and we must await the publication of definite results from the numerous shaft-sinkings now in progress before forming an opinion on this subject.

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[1] Staples, *Trans. Inst. Min. Eng.*, vol. lii, 1916–17, pp. 187–97. The writer does not agree with this author's interpretation of the relations of the Malvern and Woolhope axes to the Gloucester and Somerset Coalfield, but this question cannot be discussed here.

According to Jukes-Browne[1] the direct continuation of the axis of Ferques runs south of the Dover coalfield and is prolonged to the west as the Mendip anticline; if then we regard the last-named as the analogue of the Faille du Midi-Condroz line, the Dover coalfield is the equivalent of the coal-basin of Namur, and this gives both of the coalfields the same relation to the old plateau of Brabant and London, as it may conveniently be called.

Thus it seems justifiable to conclude that the line of contact of Carboniferous rocks with the old plateau runs somewhere along the line of the North Downs, at any rate as far west as Guildford, and then across the Downs by Andover to the northern limit of the Mendip anticlinorium. There is, however, nothing to show where the Pre-Carboniferous rocks sink below the Carboniferous in the Wiltshire region; Carboniferous limestone is known in a boring near Box (Lucknam) and Coal-measures at Bradford-on-Avon. The problem here, which seems to be insoluble at present, is to find in England, the point of inflection corresponding to Maastricht, where the Coal-measures turn round to sink under the Campine.

Unfortunately when we turn to the north-western margin of the plateau, information is very scanty. As positive facts we have the occurrence of Coal-measures at Burford (— 834 O.D.), Cambrian at Calvert and Charnian at Bletchley (in both cases at about —150 O.D. Thus it may be suggested that the boundary required runs east of Burford and between Bletchley and Northampton. For some distance here complications are introduced by the Nuneaton and Charnwood axes, while the Carboniferous rocks under Northampton are of very peculiar facies. Beyond this the only evidence is afforded by the old rocks at Ware, Culford, and Lowestoft.

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[1] *The Building of the British Isles*, 3rd ed., 1911, fig. 29, pp. 186–7.

The general suggestion here is that the overlap of the Carboniferous against the plateau again follows more or less the line of the Chalk escarpment, as it probably does south of the Thames, though why this should be so there is nothing to explain. It is probably only a coincidence, but it may have some occult meaning. It is conceivable that in some way the line of strike impressed on the Cretaceous by Tertiary movements was controlled by this deep-seated structural relation. A possible interpretation of the change of strike at the Wash is suggested on a later page.

## III. Buried Trend-lines in Eastern England.

We have now to investigate whether any evidence can be found in Eastern England of the existence of buried structural lines which might act as boundaries of coalfields analogous to those of the Campine and Dutch Limburg. As before stated, the Charnwood axis and its continuation will be taken as the western limit of the area to be thus treated. Unfortunately it so happens that within the area so defined there are very few borings and in large parts of it none, that reach the Palaeozoic floor. North of a line joining Ware, Culford and Lowestoft, there is no direct evidence for a long distance, and we have to rely on indirect indications given by the structures of the newer rocks, on the principle of posthumous movement. Further, the matter is rendered still more difficult by the immense spread of alluvium in the Fenland and the all-pervading drifts of the rest of the area, so that the " solid " maps are not nearly so helpful as they might be.

As a beginning a very brief reference may be made to Yorkshire. It is unnecessary to occupy space in showing the existence of the Cleveland and Market Weighton axes; they may be taken for granted here, but at a later stage something will be said as to their relation to certain continental structures. It is at any rate universally accepted that the Market Weighton axis underwent repeated movements during Jurassic times, and that the relations of the Jurassic and Cretaceous systems in Yorkshire are special and peculiar; although the Speeton Clay seems to be essentially a marine deposit of fairly deep-water type, it also seems to be discontinuous. It is generally agreed that the existence of any Portlandian in Yorkshire is extremely doubtful, to say the least of it.[1] It is probably significant that the strike of the Cretaceous in south Yorkshire is decidedly oblique to the Market Weighton axis, being about north-north-west.

This well-marked line of strike is continued into Lincolnshire, and there becomes exactly north-west. Moreover due east of Lincoln, at the southern extremity of the Wolds the map shows some very interesting features. This is the region of Professor Kendall's Willoughby axis, which has played so important a part in discussions of the probable easterly limit of the Yorks-Derby-Notts coalfield. The outcrops of the Jurassic and Cretaceous rocks in the area between Horncastle and Alford and down to the border of the Fens show some very suggestive features, but here care is necessary to discriminate the effects of structure and topography. The long tongue of Kimmeridge Clay that runs for several miles north-west from Spilsby occupies the valley of a small stream, and is bordered on both sides by high ground, so that it can be explained as an erosion-feature, but there is always the possibility that the position of the stream has been determined, as so often, by a slight anticlinal flexure bringing up a soft rock. The long tongue of Lower Cretaceous rocks indicated on the map around Willoughby and Alford is a different matter, as this is all low ground, and there is no topographic feature to account for it. This must be an anticlinal structure, since Chalk comes in again at a lower level in borings towards the coast. This is the Willoughby axis. As pointed out by Professor Kendall,[1] however this is not an axis of the Charnwood-Market Weighton type, with successive thinnings of strata against and over it, but rather analogous to Cleveland and the Weald, since the Jurassic strata thicken towards it. In either case, it is clearly a line of disturbance, and although the Jurassic rocks up to the Kimmeridge are unusually thick, still there is no sign of any Portlandian,[2] and the succeeding strata are of exceptional type (Spilsby-Tealby series). The Spilsby Sandstone is now generally regarded as Purbeckian, but it may be Cretaceous.

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[1] *Handb. d. regionalen Geol.*, Bd. iii, i, p. 240 (table).

The general lie of the Cretaceous rocks of this area is to be regarded as determined by the existence of an old Charnoid axis, probably synclinal in the Jurassic and anticlinal later, to which subsequent movements readily adapted themselves.

Passing due west from this area there is no information available as to underground structures for over 30 miles, till we come to the borings for coal in the neighbourhood of the Trent. It has commonly been believed that the eastern limit of the Notts Coal-measures comes somewhere along the line of that river, but a recent boring at Doddington, about four miles due west of Lincoln, has shown the presence of at least 1,000 feet of Coal-measures, making it probable that the actual limit lies even east of Lincoln,[3] but what happens between Lincoln and Willoughby we have no idea. If the Willoughby axis really represents a structure of the Weald type, the Palaeozoic rocks under it may be very deep indeed. On the other hand the

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[1] *Rep. Coal Commission*, 1905, pt. ix, p. 30.

[2] *Handb. d. reg. Geol.*, p. 240.

[3] "The Concealed Coalfield of Yorks and Notts": *Mem. Geol. Surv.*, 2nd. ed., 1926, p. 84.

Kelham boring, a mile west of Newark, touched the Carboniferous Limestone at a depth of only 2,600 feet, so the boundary is evidently very irregular, or else there is a subsidiary anticline of unknown strike here. It is supposed on slender evidence that Upper Coal-measures were struck at South Scarle, about five miles north-north-east of Kelham, at 2,000 feet. There is further some evidence of the existence of a north-south anticline through Ollerton.[1] Hence it will be seen that evidence is scanty and conflicting, and no useful conclusion can yet be drawn as to the structure and limits of this part of the buried coalfield, except that it probably extends, at least in places, well to the east of the Trent.

At Harworth Colliery, about half-way between Doncaster and Retford, a few feet below the Upper Magnesian limestone is a six-foot bed of breccia, with pebbles up to four inches in length, consisting largely of rocks of Charnian and Uriconian types.[2] Mr. H. C. Versey has suggested that these have been derived from a Charnian ridge lying to the east, perhaps the Willoughby axis.[3] This seems a long way for 4 inch pebbles to travel, and a nearer exposure seems more probable.

In the region south and east of Nottingham some information is available from various borings, but the whole thing is very vague: there are certainly one or two large faults striking east and west or nearly so, just south of that city, which should shift the boundary of the coal basin somewhat towards the east, but that is about all that can be said. To the W.S.W. of Nottingham, at Hathern, Carboniferous rocks rest on the Pre-Cambrian of Charnwood, so the boundary is clear in this direction, but the rest of it is mainly guesswork.

Immediately to the east is a very interesting area, whose structure has given rise to a good deal of discussion. This is the district around Melton Mowbray. This town lies on the middle of the outcrop of the Lower Lias, which here makes a very remarkable bend. In the latitude of Grantham the strike of the Lias turns from north-south to north-east–south-west. East of Loughborough this suddenly swings round backwards to due east–west, i.e., through 315°, for some ten miles, and then equally suddenly reverts to its former north-east to south-west direction. This change of strike is, however, much less marked in the Upper Jurassic. A study of the maps clearly suggests the occurrence of an anticlinal axis through Melton Mowbray, running east-north-east to west-south-west, while the long tongue of Middle and Upper Lias around Holwell, Eastwell, Croxton, and Belvoir might be taken to indicate a corresponding parallel syncline. This last-named structure, if taken alone, could be explained in another way. It might be of purely physiographic origin, being due to the presence in this area of a strong development of the hard and resistant ironstones of the Middle Lias, a rock which withstood denudation better than the softer facies of these divisions elsewhere. However, this explanation will not account for the second violent bend of the outcrop east of Melton Mowbray. The line of strike from Grantham to Old Dalby is in entire conformity with the general dome-like trend of the Mesozoic rocks around the southern end of the Pennine uplift, where not interfered with by Caledonian structures as on the western side, and the field evidence certainly suggests interruption of this trend by east–north–east to west–south–west folding around Melton Mowbray.

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[1] Ibid., p. 101.
[2] Ibid., p. 115.
[3] *Proc. Yorks. Geol. Soc.*, vol. xx, 1925, pp. 215–25.

The underground geology of this area has also been the subject of an interesting and important series of investigations by Thorpe and Rücker and by Cox and Trueman.[1] This work shows the existence of a post-Triassic anticline running east and west near Melton Mowbray, probably resting upon a more pronounced anticline of pre-Permian date. As a matter of fact the later uplift is clearly newer than the Lias and Inferior Oolite, but its effects disappear in the Middle Jurassic. The purely geological inferences are largely confirmed by magnetic surveys. This anticline is supposed by Cox to be continued into the area of the Wash, and to account for the change of strike in this region. At any rate this axis is an anomalous feature, which does not seem to fit in well with other known structures.

Professor Cox writes of this anticline as "east–west at Melton Mowbray", but as a matter of fact the direction is more nearly east–north–east to west–south–west, and it may be suggested that this structural direction has been to some extent influenced by an older Caledonian corrugation underlying the area.

With regard to the remaining area it may at once be admitted that the evidence is extremely vague, mainly owing to the existence of the Fenland, with its great spread of drift and alluvium. However, the map shows a long projection of rocks up to the Cornbrash as far as Peterborough, and the general lie of the strata indicates distinctly an anticlinal axis running from Market Harborough to Peterborough, parallel to the Melton Mowbray axis. It is probably significant that, as pointed out by Cox and Trueman in the first case, the Pre-Cambrian outcrops of Charnwood Forest and Nuneaton lie on the westward prolongations of these axes; and it seems highly probable that there is here an important underground barrier, though what its effect may be on the lie of the Coal-measures is very difficult to say. This barrier is very probably the determining factor in the southern termination of the coalfield south of Nottingham. The chief faults known to affect the concealed coalfield of Notts and Lincolnshire are *not* parallel to it, but run east-south-east to west-north-west, or thereabouts, nearly parallel to the Market

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[1] Cox, *Phil. Trans.*, A., vol. 219, 1919, App., p. 73, with references, and Cox and Trueman, Geol. Mag., Vol. LVII, 1920, p. 198.

Weighton and Cleveland axes; so that the Melton Mowbray and Market Harborough anticlines cannot be linked up with these dislocations.

Messrs. Cox and Trueman (op. cit., p. 199) pass over the Market Harborough anticline very lightly, but imply that it produces no effect on the rocks of the higher part of the Jurassic. At any rate the outcrop of the Cornbrash runs very far east at Peterborough, further, apparently, than can be accounted for by the valley of the Nene, and not quite in the right direction. Beyond this point the whole thing disappears under the Fenland, and nothing more can be said about it. When solid rocks reappear, east of the Fens, there is no evidence of its continuance. The Melton Mowbray and the Market Harborough anticlines are approximately 18 to 20 miles apart, and, though the fact may have no significance, it may be noted that this appears to be a common wave-length for folds in the Midlands, e.g., Charnwood and Nuneaton.

The chief conclusion to be drawn from this very speculative discussion is, that there probably exists here a broad belt of gentle folding, of early Jurassic date, which may indicate the occurrence of earlier and more accentuated movements that determined the edge of the Notts coalfield in this direction. As to the tectonic relations of this feature, it can only be said that it has not yet been found possible to bring it into harmony with any of the known trend-lines of this part of England. It may, however, be related to some of the structures described by Mr. Beeby Thompson in the Lias of Northamptonshire. In the case of the Melton Mowbray anticline at any rate, it seems impossible to attribute the whole thing to Tertiary disturbance, since the Upper Jurassic strata are not affected, though this cause might account for the more southern line of disturbance.

In a communication to the Institution of Mining Engineers, Professor Fearnsides has put forward some interesting and suggestive ideas as to the relation of structures in the Yorks-Derby-Notts coalfield to Charnian trend-lines.[1] Although the present writer is not able to accept all of these conclusions in detail there can be no doubt that they form an important contribution to the general discussion of the subject. Professor Fearnsides here seems to assume that the Charnian direction is given by a line joining Ingleton, Charnwood Forest and Bletchley. In the earlier paper so frequently cited here the writer has given reasons to show that Charnwood Forest and Bletchley do not lie on the same axial fold-line, but on parallel ones; the Charnwood-Bletchley line is not in point of fact parallel to the general strike of the Charnian rocks, which is almost exactly north-west to south-east, passing through Leicester, Orton and Ware, and the Bletchley boring is to be regarded as lying on the Nuneaton axis. These alignments make the strike of the

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[1] W. G. Fearnsides, *Trans. Inst. Min. Eng.*, vol. li, 1916, pp. 409–48.

Charnoid lines parallel to the Willoughby axes and those of Belgium and Holland. On this assumption the continuation of the strike of the Ingletonian rocks comes somewhere a little west of Bradford, just at the sharp angle of the Yorkshire coalfield and points for Newark and the Fenland. There is nothing to show whether the structure at Ingleton is anticlinal or not, and it is a long way from other exposures, but the general form of the Yorks coalfield at its north-west corner certainly suggests a north-west to south-east synclinal basin, with its central line about half-way between the Charnwood and Willoughby axes. However, there are undoubtedly many minor undulations, as well as faults, in this area.

## IV. Continental Equivalents.

Disturbances of Jurassic age are well known on the continent of Europe, beginning even between the Trias and the Lias far to the south-east, as in the Dobrudsha, and apparently travelling north-westwards in the successive stages of the Jurassic, until they culminated in the general gap in the succession above the Kimmeridge which is so conspicuous a feature in western Germany, Holland, and eastern England. These movements constitute the Cimmerian phase of the Saxonian fold-system of Stille,[1] a system which is specially characterized by north-west to south-east trend lines, as revealed so strongly in the underground structure of western Germany and Holland. This region has already been referred to briefly, but a few more details, abstracted chiefly from the works of Stille, Salfeld, van Waterschoot van der Gracht, and others, must now be given.

Considering only the western part of the area, we find to the south an old continental area, including the Devonian and older massif of the Rhine and the Ardennes, with their northerly continuations in the coalfields of the Ruhr, the Campine, the plateau of Brabant, and south-eastern England. North of this area an old shore line has been traced running in a sinuous course from Germany through central Holland and presumably across the North Sea towards England. South of this shore-line are found only scattered patches of Mesozoic rocks, often in very incomplete series, and frequently showing fresh-water facies (often mis-named estuarine facies). To the north of this line the Mesozoic rocks are much thicker and the series more complete, though still with discontinuities at certain more or less definite horizons, of which the Portlandian is the most conspicuous and widespread, so that the Lower Cretaceous is often strongly transgressive.

The southerly continental region can again be sub-divided into two areas :—

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[1] H. Stille, " Die kimmerische (vorcretasiche) Phase der saxonischen Faltung des deutschen Bodens " : *Geol. Rundschau*, vol. iv, 1913, pp. 362–83, with a very good bibliography.

(*a*) A region intensively folded in the Permo-Carboniferous by pressure from the south; the Armorican-Variscan fold-system.

(*b*) a region not then markedly disturbed, including the plateau of Brabant and London.

The last-named acted as a horst, against which the fold-pressure exhausted itself in vain.

To the north of this again comes a region in which the structure is of an altogether peculiar type, consisting of a series of horsts and rift-valleys, all of which have a pronounced north-west to south-east trend. The different elements of this structure are bounded by dislocations, but these are not all simple vertical faults; in many of them there is distinct evidence of over-thrusting, mostly towards the south-west, and furthermore it is established by Stille and others that the blocks themselves are in many places distinctly bent into anticlinal and synclinal forms.

It is obvious that there must be some relation between this very well-marked Saxonian fold-system in Belgium and Holland, which is largely of latest Jurassic age, and the various Jurassic fold-lines of Charnian trend which have been established in England in the earlier part of this, and in the former paper by the writer, as before cited. The parallelism of the structural features and the frequent coincidence in age are too marked to be the result of mere chance.

It is impossible here to give details as to the structure and location of the German and Dutch areas referred to. For such reference must be made to the literature already cited. Only one striking example will be here mentioned, namely, the Teutoburger Wald, that strange ridge that sticks out of the North German plain near Osnabrück, and is such a conspicuous feature of the railway journey from any of the Dutch ports to Bremen and Hamburg. Here there was certainly strong folding in Portlandian times, and the strike is exactly Charnian. Further the north German salt-domes are arranged in rows exactly parallel to this strike.

The point of immediate interest here is as to whether any definite connexion can be found between known structures on the continent and similar structures in the British Isles. On this point Dr. W. A. J. M. van Waterschoot van der Gracht has expressed some opinions in the work already cited. The following is a somewhat condensed translation of part of his conclusions on this subject:—

"In our country [Netherlands] everything disappears under the thick Upper Tertiary and Diluvial covering of the North Sea depression and further west we find no clear indications until we come to the English uplift. Here again there are Mesozoic fold-axes, which disappear under the North Sea in exactly the same direction, to the south-east. Specially conspicuous are the axes of the Cleveland Hills and of Wharfe-Market Weighton, which without the slightest doubt belong to the same system as the North German salt-lines. These axes have been especially described by Professor Kendall.

"In the Cleveland axis, where already movement had begun in the upper Palaeozoic, we have—just as in the Teutoburger Wald—pronounced sedimentation during the whole Jurassic and Cretaceous but strong folding after the Cretaceous. In the Market Weighton axis the relations are somewhat different: here there are also signs of late Palaeozoic folding, but a renewed uplift began to show itself in the Lower Lias. The Upper Cretaceous, unfolded, transgresses on to folded Lias.

"This succession of a southerly Mesozoic and a northern Tertiary zone of folding, along the northern margin of the early Palaeozoic massif of Norfolk and Yorkshire is in exact agreement with what we know in the Rhineland, Egge, Osning, Teutoburger Wald and at Winterswijk. Furthermore it is striking that the Teutoburger chain lies exactly on the continuation of the Cleveland axis, and the continuation of the Wharfe axis brings us into the neighbourhood of Winterswijk. This linking up of axes across the North Sea is admittedly a large order, and I am far from insisting on it dogmatically, but I would like to mention the striking fact that these folds lie just in the right direction, and as a matter of fact were developed at similar times and in the same order."[1]

In discussing the suggestions here made we encounter what has always been a difficulty to tectonic geologists, namely that a plane map does not, and cannot, show actual directions correctly over a large area; there must always be more or less distortion, although map-projections vary a good deal in this respect. Accurate conclusions can only be drawn from a globe and few globes are large enough to be satisfactory, or to show the direction of small hill ranges with sufficient plainness.

The most important physiographic feature of Germany for the purposes of this discussion is the line of the Böhmerwald—Thüringerwald and its direct continuation the Teutoburgerwald. In the south the strike, as shown on a fairly large-scale orographic map, is north-west, in the Thuringian region west 40° north, and near Osnabrück west 33° north, thus showing a slight curve concave to the south-west. The question that next arises is as to whether this curve is sufficient to bring this axis into line with any of the English axes.

Now a careful inspection of English maps shows that the Cleveland and Market Weighton axes are almost exactly parallel and that their strike is west 5° north, whereas the Willoughby axis is very nearly true north-west. The total distance from Osnabrück to Market Weighton is about 370 miles. Therefore if the lines are to be joined up, there must be a curvature of 28° in this distance. The figures quoted above from the German map show a curvature of about 7° in 200 miles; hence the bending must become more acute if this line is to join up even to the more northerly Cleveland axis. This is of course not impossible, but the correlation does not seem very satisfactory.

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[1] The translation of the last sentence is admittedly very free, but it is believed to express the author's meaning to English readers better than a more literal rendering could do.

However, when the figures quoted above are applied to the International Geological Map of Europe the agreement is very much better, and it seems quite possible to interpret the Cleveland or the Market Weighton axes, or both, as a continuation of the Thüringer-Teutoburger line. It has to be remembered that these two British axes are not analogous, but of essentially different character, the Cleveland axis being of the Wealden type, with thick and nearly continuous sedimentation, while the other shows thin sedimentation with frequent gaps and marked overlaps. It seems improbable therefore that they belong to the same system ; a large part of the uplift along the Cleveland axis was pre-Permian, while at Market Weighton the Permian is very thick, and there is little likelihood of a pre-Permian ridge here.

There remains the question of the Willoughby axis ; this is very far from being parallel to the general trend just sketched above, being, so far as can be seen from the short length of it visible, almost exactly north-west, parallel to the Charnian axis, but making a sharp angle with the Market Weighton axis. Therefore it cannot be worked in with the more northerly axis.

## V. Summary and Conclusions.

The foregoing sketch brings out marked resemblances in the geological features of eastern and southern England on the one hand, and the neighbouring parts of the continent on the other. In both areas we find an old plateau of pre-Devonian rocks, against which Devonian and Carboniferous rocks are violently thrust from the south by Armorican and Variscan folds, giving rise to highly complex coal-basins in Belgium, France and Somerset, a type of structure possibly to be encountered in the future in Kent. In Belgium this plateau sinks to the north-east under the Campine coalfield, while in England its north-west margin is complicated by the incidence of posthumous folds of Charnian strike.

In eastern England, east of the Charnwood line, there is evidence for the existence of Professor Kendall's Willoughby axis, with north-west strike ; between this and the Charnwood line there are indications of similar parallel buried trend-lines in the folding and faulting of the visible Yorks-Derby-Notts coalfield, and also, as suggested by Professor Fearnsides, in the general shape of this basin.

Further to the north, however, the general line of the Cleveland and Market Weighton axes is not Charnian, being about west 5° north. The Market Weighton axis, which is of Charnian type, with many repeated movements, does not form the boundary of the coalfield ; this is in fact constituted by the southern flank of the broad Cleveland uplift, which is of Wealden type ; an anticline superposed on an earlier sinking area.

Throughout the whole of eastern England, Portlandian strata are missing and important earth-movements occurred at this time, correlated with the Saxonian disturbances of the continent, which were a combination of block-faulting and lateral thrust, leading to a dominant north-west to south-east strike in the resultant horsts and rifts.

In the neighbourhood of Melton Mowbray and Market Harborough the disposition of the outcrops of the Lower Jurassic rocks gives indications of the existence of two buried ridges striking slightly north of east and south of west, entirely discordant with the rest of the tectonic lines of this part of the country and of unknown relationship, but probably limiting the main coal-basin on this side. Similar structures may be the cause of local discontinuities in the Lower Jurassic of Northants, as described by Mr. Beeby Thompson.

In their general relations there are remarkable analogies between the eastern and western halves of the old Palaeozoic plateau, now separated by the North Sea, but in eastern England, north of London, there are not enough borings to show whether there is a continuation of the horst and rift structure as revealed by borings in Belgium and Holland. Such structures may exist under the Cretaceous and alluvium, but have not yet been demonstrated.

It seems probable that the south-eastern limit of the Yorks-Derby-Notts coalfield is formed by an anticlinal ridge visible in the Lower Jurassic near Market Harborough, which may indicate the existence of an older pre-Permian anticlinal structure below. On the whole it seems probable that the south-east limit of this fold system is quite near to the north-west margin of the Palaeozoic plateau, and therefore there cannot be much, if any room for coal-basins between them.

The possible correlation of the Thuringian—Teutoburgerwald fold axis with British anticlines is considered. It may possibly be linked up with Cleveland or Market Weighton, but not with the Willoughby axis.

The evidence as a whole is distinctly unfavourable to the existence of coal basins in East Anglia south of a line from Market Harborough to the Wash, although there might be a small patch more or less co-extensive with the county of Huntingdon and the southern Fenland between Ely and Wisbech ; it is more probable however that Carboniferous strata, if here present, would be of the peculiar type found in borings at Northampton, which are probably Viséan, rather than Coal-measures.

# The Cretaceous Shales of Jamaica.

By C. T. Trechmann, D.Sc., F.G.S.

(PLATES I–IV.)

BEDS of shale, sandstone and conglomerate containing Upper Cretaceous fossils occur at several places in Jamaica, and in every instance that I know of they are found to be more or less in close association with Rudist limestones. They generally occur below the limestones with Rudistae but in at least one locality, that at St. Ann's Great River, fossiliferous shales occur immediately above and also a considerable distance, 1,000 feet or so, below a bed of Rudist limestone.

In the present imperfect state of our knowledge of the structure and tectonics of the Blue Mountain rocks or Trappean Beds, which comprise the basement series of the island, it is not easy to form an opinion as to where in this great sequence the fossiliferous shales and Rudist limestones should come. They are certainly not at the top, since in some localities a great thickness of shale or conglomerate overlies the Rudist limestone. For instance, at Trout Hall a thick Trappean conglomerate follows above the limestones and shales with Rudistae, and near the upper end of the Great River Valley very thick beds of shale apparently without fossils overlie the Rudist limestones. On the other hand there is beneath the fossiliferous beds a vast thickness of more or less metamorphosed and crushed shaley and conglomeratic material which builds up the greater part of the massif of the Blue Mountain range. Fossils may yet be found in some of the rocks that form the higher peaks which rise to 7,300 feet in Blue Mountain peak[1] but at present the condition of these crushed, welded, metamorphosed, intruded and strongly folded and possibly piled up beds does not seem to promise the occurrence of many fossils.

The fossils that occur below the limestones with Rudistae are the oldest known in Jamaica. Jurassic fossils occur at several localities in Cuba but none earlier than Cretaceous have yet been found in Jamaica. Fragments of rock such as gneiss, schist, marble and limestone derived from older formations which are not now to be seen in Jamaica occur in the conglomerates both of the Trappean (Cretaceous) and of the Carbonaceous Shale or Richmond beds (Basal Eocene) in Jamaica but up to the present no trace of any older or pre-Cretaceous fossils has been seen among them.

J. G. Sawkins[2] mentions the occurrence of shales with *Hamites*, *Baculites*, *Pholadomya*, and *Trigonia* at Providence near Port Antonio, otherwise his memoir does not seem to make any definite reference to fossiliferous Cretaceous shales in other localities in the island.

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[1] Mr. G. M. Stockley, F.G.S., told me recently that he saw a fossiliferous shale bed about 300 feet below the top of Blue Mountain peak but the fossils he collected there were unfortunately lost.

[2] Reports on the Geology of Jamaica, *Mem. Geol. Survey*, 1869, p. 78.

## LOCALITIES OF THE CRETACEOUS SHALES.

I have examined and collected from the Cretaceous fossil-bearing shales in localities which extend over practically the whole length of Jamaica. Though they are more or less closely associated with the Rudist limestones, the shales yield a fauna almost entirely distinct from that of the limestones. This difference however seems due more to the nature of the deposits than to any great difference in age of the fauna.

## GREEN ISLAND OR HAUGHTON HALL, WESTERN JAMAICA.

During a recent visit to this locality in calcareous shales immediately beneath the *Barrettia* limestone I found the following fossils: *Neithea quinquecostata* and *quadricostata*, *Spondylus* sp., and a coral or two. Shales still further below the limestone, however, appeared to be devoid of fossils. I have already published a sketch showing the mode of occurrence of the *Barrettia* limestone here, which is not indicated on Sawkins' map.

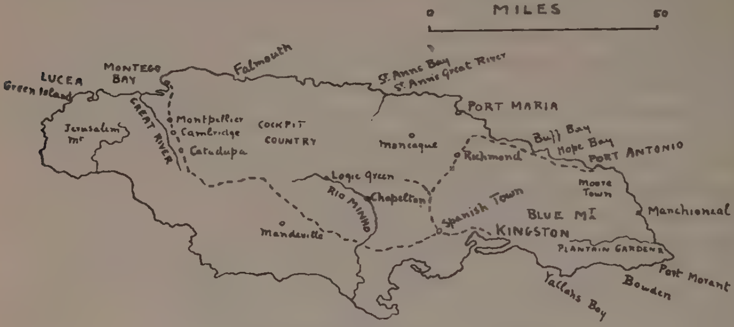

FIG. 1.—Locality sketch-map of Jamaica.

## CAMBRIDGE AND CATADUPA DISTRICT AND THE VALLEY OF THE GREAT RIVER, WEST CENTRAL JAMAICA.

Beds of shale occur both above and below the Rudist limestones in this area. The best locality for fossils is the stretch of railway line between Cambridge and Catadupa stations. Here a bed of limestone about 40 feet thick full of Rudistae overlies a thickness of 100 feet or more of red and grey calcareous and nodular shales. The sequence of limestone and shale is repeated by dips and small faults several times along the railway line between these places and again to the south of Catadupa. At one place the limestone passes down into a grey shale with branching corals and Rudistae, and about 20 feet below this there is a band of reddish shale with numerous fossils, *Trigonia emoryoides*, *Cucullaea catadupensis*, etc. At another place a short distance away a bed about 30 feet beneath the limestone contains *Roudaireia jamaicensis*, *Septifer acutus*, *Neithea quinquecostata* and numerous other species. No cephalopods occurred in this district and it is not easy to trace any very definite sequence of fossils in the shale beds.

Red shales on the sides of the road leading from Catadupa down the valley of the Great River yielded *Septifer acutus*, *Modiolaria*, and other forms. Similar shales on the south side of the valley opposite Catadupa below the Rudist limestone proved to be very poor in fossils and yielded only a species of *Cardium*. Along the railway line the Rudist limestones come very close beneath the Yellow Limestone of Lutetian age which overlies the Cretaceous beds unconformably and only a few feet of shales intervene, but further up the Great River Valley a very considerable thickness of apparently unfossiliferous red shales and sandy clays overlies the Cretaceous limestones.

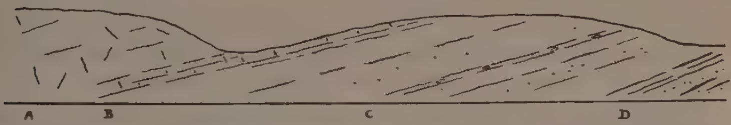

Fig. 2.—Section of Cretaceous beds along part of the railway line between Cambridge and Catadupa, Jamaica.

A. Rudist Limestone with *Titanosarcolites*, *Biradiolites*, corals, etc.
B. Shaley Limestone with small *Rudistae* and branching corals.
C. Red nodular shales with *Trigonia emoryoides*, *Cucullaea*, *Neithea quinquecostata*, etc.
D. Dark calcareous shales, about 50 feet below the limestone, with *Roudaireia*, *Septifer*, *Cardium*, *Modiolaria*, *Ranina*, *Cyclolites* and other fossils.

Mr. R. Cory of Catadupa kindly gave me a number of well preserved fossils which he had gathered in various exposures from time to time around his home. Some of these evidently belong to the Cretaceous shales and show that this district is a very prolific one. They were collected in various stream courses as well as along the railway cutting, but the precise locality in most cases was not recorded. Among them are such forms as *Turritella* cf. *forgemolli*, *Exogyra* cf. *overwegi* etc., which may have come from shale beds newer than the Rudist limestone of the district.

## The Watershed of the Rio Minho, Central Jamaica.

In the section of Rudist limestones at Logie Green a bed of calcareous shale occurs rather low down in the sequence but some distance above the limestone with *Praebarrettia sparcilirata* and *Lapeirousia nicholasi*. It yielded *Neithea quadricostata*, a species of *Lima* and a few other fossils.

On the southern slope and in the bottom of the valley of the Rodons or White Rock River there are some small outcrops of

Cretaceous limestone among a great mass of red Trappean shales. Sawkins indicates these on his map by two small patches of blue a few miles north of Logie Green. I found here a considerable thickness, 100 feet or more, of grey limestone, massive in some parts and argillaceous in others. The lower beds were largely made up of broken fragments of the large *Caprina*-like *Titanosarcolites*. Rather higher up a marly Rudist limestone with lenticular foraminifera occurs and this passes up into a compact limestone with *Biradiolites jamaicensis* and other Rudistae. Beneath these limestone beds, a short distance above the river a series of about 50 feet of grey calcareous nodular shales occurs which contain *Pholadomya jamaicensis*, *Septifer acutus*, *Cardium* spp., and specimens of *Hemiaster* sp.

The sequence of Rudist limestones overlying nodular shales in this locality is very similar to that seen along the railway cutting between Cambridge and Catudupa.

### St. Ann's Great River Valley, 2 Miles South-East of St. Ann's Bay, Middle of the North Coast of Jamaica.

J. G. Sawkins on page 199 refers to these beds as the upper conglomerates of the Trappean series, but the occurrence is not indicated on his map. Dr. C. A. Matley examined and mapped the exposure in 1924 and it was further examined in April, 1925, by Messrs. J. V. Harrison and P. T. Cox to whom I am indebted for several fossils collected there. I have paid several visits to the locality with a view to examining the sequence of the beds. A thick series of Cretaceous beds here forms a small inlier and crops out from beneath Eocene basement conglomerates and later Tertiary white limestones and marls. I have already published a short description of these beds [1] but I omitted to mention the fact that fossils occur in the shales not only immediately above the Rudist limestone but also a very considerable distance below it. Also I have recently collected *Barrettia* in this limestone.

The Cretaceous beds dip southwards or more or less steeply up-stream, the limestone at an angle of about 45 degrees.

The section, after further examination, appears to me as follows :—

| | | *Thickness in feet.* |
|---|---|---|
| 1. | Tertiary white marls passing up into white limestone | ? |
| | Unconformity ? | |
| 2. | Conglomerates containing numerous limestone pebbles. Richmond or basal eocene. Unconformity . . | ? |
| 3. | Grey and black shales becoming calcareous towards the base. Fossils plentiful ; *Neithea quadricostata*, *Plicatula* cf. *andersoni*, *Pholadomya jamaicensis*, *Gosavia* sp., *Glauconia matleyi*, *Aporrhais* sp., *Cerithium* cf. *libycum*, and other forms. The gastropoda occur mostly in calcareous shales a few feet above the limestone . | About 40 |

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[1] "Cretaceous Limestones of Jamaica," Geol. Mag., Vol. LXI, No. 723, Sept., 1924, p. 390.

| | | *Thickness in feet.* |
|---|---|---|
| 4. | Clayey limestone with fragments of Rudistae . . . | 10 |
| 5. | Grey and pink nodular limestone containing complete and broken specimens of *Biradiolites cancellatus* and *B. subcancellatus*, *Barrettia monilifera*, and a large specimen of *Laperiousia nicholasi* . . . . . | 12 |
| 6. | Massive conglomerate with many igneous and a few limestone pebbles . . . . . . . . | 50 (?) |
| 7. | Grey and blackish shales and shaley sandstones. A bed of small *Corbula* occurs in these shales about 800 feet below the Rudist limestone and below this a bed with *Turritella cardenasensis*, *Nerita subcompacta*, *Natica* sp., *Ostrea* sp., *Echinoderm* spines, etc. About 1,000 feet below the limestone a specimen of *Inoceramus* cf. *balticus* was collected by Mr. J. V. Harrison . . | over 1,000 |
| 8. | Grey nodular shales with calcareous bands, no fossils seen | 300 (?) |
| 9. | Thick conglomerates and sandstones, base not seen . | ? |

## PROVIDENCE NEAR PORT ANTONIO, NORTH-EASTERN JAMAICA.

Sawkins refers to the shales in this district and reports the occurrence of *Hamites*, *Baculites*, *Pholadomya*, and *Trigonia* in them. In addition to these fossils I was fortunate in finding numerous others. These comprised some true Ammonites, *Epigoniceras*, and *Parapachydiscus*, which occurred in a bed considerably below that containing the *Hamites* and *Baculites*. This is the first and only instance so far as I am aware of the finding of coiled Ammonites in Jamaica.[1]

A road which has been constructed from Port Antonio southwards to a habitation called Mooretown reveals good sections of Trappean shales and conglomerates, Cretaceous limestones, and Carbonaceous shales or Richmond beds for a distance of 8 or 9 miles. The road passes about half a mile east of a farm or "pen" called Providence which is probably the place where Sawkins obtained his fossils. The sequence of the Cretaceous shales exposed along the sides of this road is perhaps best indicated by a section which I drew up. (Fig. 3.)

Around the farm of Providence there is a series of exposures which if mapped in detail would doubtless explain much of the relationship of the various beds to one another and the extent to which the Cretaceous beds were folded and denuded before the deposition of the Richmond or basal Eocene conglomerates upon them. On a driving path which leads from the road to the farm I found an unconformable junction of the Richmond shales resting on the Cretaceous Providence shales. The Richmond shales are recognized by their lack of fossils, their dark joints, and the fact that they break up into small pieces with curved surfaces of fracture. They rest here on sandy calcareous nodular shales with fossils, whereas a few hundred yards to the north-east the Richmond shales rest with approximately the same dip on Cretaceous Rudist limestone, as I have indicated in the section.

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[1] L. F. Spath, GEOL. MAG., Vol. LXII, No. 727, Jan., 1925, pp. 28–32.

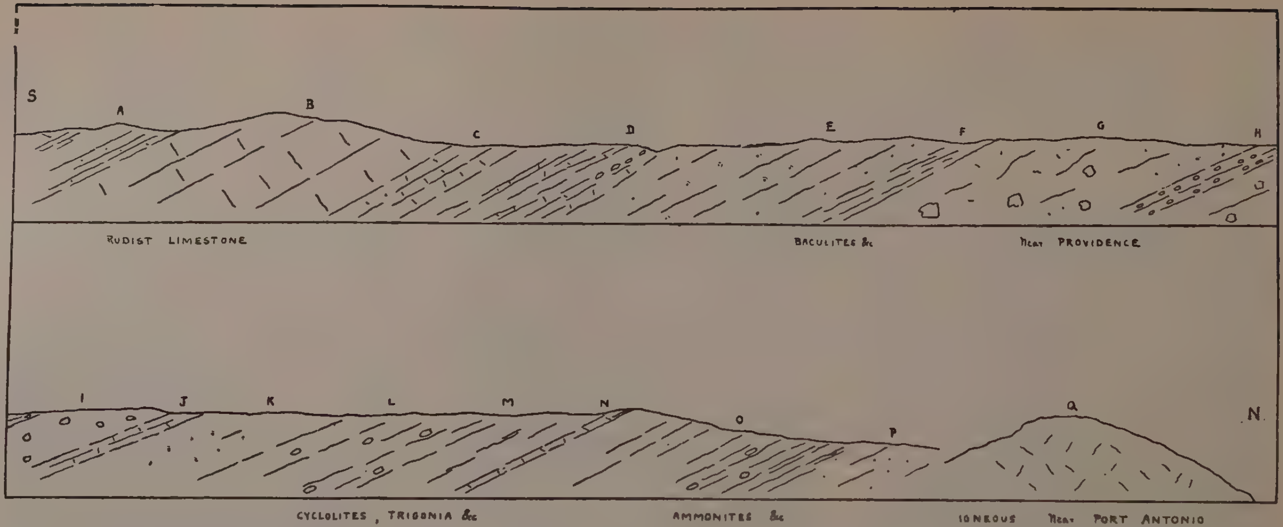

FIG. 3.—Sketch of section approximately north and south from Port Antonio to beyond Providence, N.E. Jamaica, showing sequence of beds as observed by the Author, of Cretaceous and early Tertiary age. Igneous, Trappean, Rudist limestone, and Richmond beds. Length of section about 2 miles. A: Grey shales belonging to the Richmond Series (no fossils). B: Rudist limestone; hard white limestone with sections of *Coralliochama*, *Radiolites*, corals, bivalves, etc. C: Limestone full of large and small pebbles of igneous rocks, no fossils. D: Grey shales with bands of limestone and calcareous nodules, small fossils on surfaces, echinoderm remains, etc. E: Red sandstone, unfossiliferous. F: Red shales with numerous fossils; *Hamites*, *Baculites*, *Cyclolites*, etc. G: Thick grey sandstone with occasional large boulders of porphyritic rocks and smaller pebbles. H: Conglomerate made up of igneous pebbles. I: Sandstone with igneous and occasional limestone pebbles. J: Calcareous sandstone with *Pecten* and Sharks' teeth. K: Soft red sandstone. L: Shales with rounded pebbles of igneous rocks, full of *Cyclolites* in places, *Trigonia*, etc. M: Sandy shales. N: Calcareous band (no fossils seen). O: Red shales with occasional calcareous nodules; Ammonites (*Parapachydiscus*, etc.), *Neithea quinquecostata*, *Cyclolites*, numerous Gasteropods, etc. P: Sandstones. Q: Porphyritic intrusive mass.

FOSSILS FOUND IN THE CRETACEOUS SHALES OF JAMAICA.

| | Middle Senonian | Campanian | | | Maestrichtian | |
|---|---|---|---|---|---|---|
| | St. Ann's Great River 900–1000 ft. below the *Barrettia* Limestone. | Cambridge Catadupa Railway Cutting. | Near Catadupa, locality uncertain. | Providence Shales. | *Barrettia* and Rudist Limestones. | St. Ann's Great River above *Barrettia* Limestone. |
| CEPHALOPODA. | | | | | | |
| *Epigoniceras* sp. ind. | | | | + | | |
| *Parapachydiscus* aff. *stallauensis* Spath | | | | + | | |
| ,, cf. *gollevillensis* d'Orb. | | | | + | | |
| *Glyptoxoceras* cf. *rugatum* Forbes | | | | + | | |
| *Baculites* sp. ind. | | | | + | | |
| GASTEROPODA. | | | | | | |
| *Nerita subcompacta* sp. nov. | + | | | | | |
| *Solarium* sp. | | | | | | + |
| *Amauropsis* cf. *altilirata* Böse | | + | | | | |
| *Ampullina* sp. | | | | + | | |
| *Lunatia* cf. *larteti* Böhm | + | | | | | |
| *Glauconia matleyi* sp. nov. | | | | | | + |
| *Turritella* cf. *forgemolli* Coq. | | | + | | | |
| ,, cf. *overwegi* Quaas | | + | | + | | |
| ,, aff. *cardenasensis* Böse | + | | | | | |
| *Vermetus* cf. *libycus* Quaas | | | | | | + |
| *Cerithium* cf. *libycum* Wanner | | | | | | + |
| ,, cf. *dachelense* Wanner | | | + | | | |
| *Ringicula* sp. | | | | + | | |
| *Rostellaria* (*Calyptrophorus*) sp. | | | | | | + |
| ,, spp. | + | + | | + | | |
| *Aporrhais* sp. | | | | + | | |
| ,, sp. | | | | | | + |
| *Eocithara jamaicensis* sp. nov. | | | | + | | |
| *Murex* (?) sp. | | | | + | | |
| *Gosavia* sp. | | | | | | + |
| *Lyria* spp. | | | + | + | | + |
| *Volutilithes* sp. | + | | | | | |
| *Fusus* (?) sp. | | | | + | | |
| LAMELLIBRANCHIATA. | | | | | | |
| *Cucullaea catadupensis* sp. nov. | | + | | | | |
| *Barbatia* sp. | | | | + | | |
| *Septifer acutus* sp. nov. | | + | | + | | |
| *Modiolaria catadupensis* sp. nov. | | + | | | | |
| ,, sp. | | + | | | | |
| *Avicula* sp. | | | | + | | |
| *Inoceramus* cf. *balticus* Böhm | + | | | | | |
| *Exogyra* cf. *overwegi* Buch. | | | + | | | |
| *Gryphaea* cf. *hypoptera* Wanner | | | | + | | |
| *Ostrea* cf. *conica* Sow. | | + | | | | |

| | ? Middle Senonian | Campanian | | | Maestrichtian | |
|---|---|---|---|---|---|---|
| | St. Ann's Great River 900–1000 ft. below the *Barrettia* Limestone. | Cambridge Catadupa Railway Cutting. | Near Catadupa, locality uncertain. | Providence Shales. | *Barrettia* and Rudist Limestones. | St Ann's Great River above *Barrettia* Limestone. |
| *Ostrea* cf. *delettrei* Coq. | + | | | | | |
| *Trigonia* sp. | | | | + | + | |
| „ cf. *cerulea* Whitf. | | | | + | | |
| „ *emoryoides* sp. nov. | | + | | | | |
| *Camptonectes* cf. *curvatus* Gein. | | + | | + | | |
| *Pecten* cf. *septemplicatus* Nilsson | | | | + | | |
| *Amusium* (?) cf. *membranaceum* Nilsson | | | | | | + |
| *Neithea quinquecostata* J. Sow. | | + | | + | + | |
| „ *quadricostata* J. Sow. | | + | | | + | + |
| „ sp. | | | | | | + |
| *Plicatula* cf. *andersoni* Newton | | | | | | + |
| „ cf. *urticosa* Morton | | | | | | + |
| *Pholadomya jamaicensis* sp. nov. | | + | | + | | + |
| „ *tigroides* sp. nov. | | | | + | | |
| *Thracia* (?) sp. | | | | + | | |
| *Pleuromya* sp. | | + | | | | |
| *Roudaireia jamaicensis* sp. nov. | | + | | | | |
| *Veniella* sp. | | | | + | | |
| *Cardita* sp. | | + | | | | |
| *Antillocaprina* (?) sp. | | + | | | | |
| *Cardium* cf. *gosaviense* Zittel | | + | | | | |
| *Cardium* (*Fragum* ?) sp. | | | + | | | |
| *Laevicardium* (?) sp. | | + | | | | |
| *Laevicardium* sp. | | + | | + | | |
| *Cardium* cf. *becksii* J. Müll | | | | + | | |
| *Cytherea catadupensis* sp. nov. | | + | | | | |
| „ spp. | | | | | | + |
| *Legumen* cf. *appressum* Conrad | | + | | + | | |
| *Legumen* (?) sp. | | + | | + | | |
| *Tellina* (?) sp. | | + | | + | | |
| *Corbula* cf. *parsura* Stol. | + | | | | | |
| *Raeta* or *Raetomya* sp. | | | | + | | |
| BRACHIOPODA. | | | | | | |
| *Terebratulina* (?) sp. | | | | + | | |
| COELENTERATA. | | | | | | |
| *Cyclolites* spp. | | + | + | + | | |
| CRUSTACEA. | | | | | | |
| *Ranina* sp. nov. | | + | | | | |

The following sequence of Cretaceous or Trappean beds in descending order was observed in the bed and sides of the West Town River down the slope below the house of Providence.

1. A considerable thickness of dark nodular concretionary shales with scattered rounded conglomeratic pebbles in them, dipping steeply in an easterly direction and containing a few fossils, *Cyclolites*, *Raeta* sp.,[1] *Corbula* sp., *Terebratula* sp.
2. A series of dark reddish shales similar to those seen in the roadside section but the fossils are few and badly preserved; they include *Cyclolites* sp., *Pholadomya jamaicensis* and others.
3. A thick bed of polygenetic conglomerate made up of well rounded pebbles and masses of various sizes. This hard band forms a picturesque cascade over which the stream falls and is very similar to the Trappean conglomerates that one sees at other places in the Blue Mountain country.

## Description of the Fossils.

### *Nerita subcompacta* sp. nov. (Pl. IV, Figs. 34 and 35.)

*Description.*—Shell small, thick, rounded, compact, of 3 or 4 whorls, the spire in some specimens rather elevated in others flattened, the sutures very shallow, surface smooth with irregular flattened growth lines and occasional traces of wavy or zig-zag colour markings. The under side flattened; aperture semi-circular, the inner and outer lips thickened and rounded, the inner lip is calloused and grooved before and behind and bears about six rather sharp teeth the two central ones being the largest. Height 10 mm., width 12 mm.

*Locality.*—St. Ann's Great River, in shales about 800 feet below the *Barrettia* limestone.

*Remarks.*—It comes near in shape to *N. compacta* Forbes from the Arrialoor group of Pondicherry, India (Stoliczka, *Cret. Fauna S. India*, 1868, vol. ii, p. 339, pl. xxviii, figs. 4 and 4*a*), but the Jamaican shell has a thicker inner and outer lip and the teeth are not so strong.

### *Solarium* sp. (Pl. IV, Fig. 32.)

Shell rather thick, the apex obscured, sutures shallow, the surface has about 9 faint irregular spiral ridges crossed by growth lines giving a faint reticulation. Beneath the shell is widely umbilicate, the whorls tabulate below and independently of the suture, growth lines are coarser than on the upper side and are rather foliaceous and several fine spiral ridges form a faint reticulation. The aperture is trapezoidal in section. Diameter 18 mm., height 7 mm. Collected in shales above the *Barrettia* limestone at St. Ann's Great River by Dr. Matley. A rather similar shell *S. arcotense* Stol. occurs but is rare in the Arrialoor beds of South India. (*Pal. Ind.*, 1868, vol. ii, p. 255, pl. xix, fig. 29.)

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[1] See Geol. Mag., Vol. XLI, Jan., 1924, p. 18, where I described this shell and referred it doubtfully to the Richmond or Carbonaceous shale series. There is no doubt now that this bed is a Cretaceous Shale and that *Raeta* sp. found there is a Cretaceous fossil.

### *Amauropsis* cf. *altilirata* Böse. (Pl. I, Fig. 10.)

Shell large, of about 6 whorls which enlarge rapidly, the spire elevated, the sutures well sunken, below which the whorls are tabulate and broadly concave. The sides of each whorl are gently rounded and the growth lines fine and close set. The aperture is wide and oval, the outer lip thin, the inner lip thinly calloused. Height 60 mm., diameter 49 mm. It occurs in shales about 30 feet below the Rudist limestone on the Cambridge-Catadupa railway cutting.

This shell is larger than the Mexican *Natica* (*Ampullina*) *altilirata* of Böse from the Lower Senonian of Cardenas (*Boletin Instituto geol. Mexico*, No. 24, 1906, p. 61, pl. xiii, figs. 2, 3, and 7) and seems to have a larger body whorl and more tapering spire, but resembles it in general appearance. *Amauropsis* seems to me a more suitable genus than *Ampullina*.

### *Ampullina* sp. (Pl. IV, Fig. 24.)

Shell thin, of 4 or 5 whorls, the last one spacious, the suture sunken. The surface is smooth with fine growth lines, the aperture rounded with only slight traces of an inner callosity. Height 24 mm., width 23·5 mm. From the Providence shales.

### *Natica* (*Lunatia*) sp. (Pl. IV, Fig. 12.)

A small naticoid shell with elevated spire and rather sunken sutures was found beneath the *Barrettia* limestone at St. Ann's Great River. It resembles figures by Spengler of *Lunatia* cf. *larteti* Boehm from Tharia Ghat, Assam (*Pal. Ind.*, N.S., vol. viii, mem. i, 1923, pl. ii, figs. 27 and 28).

### *Glauconia matleyi* sp. nov. (Pl. II, Fig. 11.)

*Description.*—Shell of 23 or more whorls, conical, tapering, the sides flat becoming slightly concave towards the apex, the sutures inconspicuous. On each whorl just below the suture there is a rather broad raised flattened band with moderately prominent rounded nodes: below this a groove with fine spiral thread lines; below this a raised flattened band narrower than that above with blunt rectangular nodes; below this another groove with thread lines, and below this a low rounded ridge without nodes. Both of the noded bands bear fine spiral thread lines. The ornament weakens on the early whorls. The aperture is not preserved and the growth lines can hardly be seen.

*Dimensions.*—Length about 100 mm., diameter at base 44 mm.

*Locality.*—St. Ann's Great River, immediately above the Rudist limestone, a large specimen collected by Dr. C. A. Matley and fragments found by Messrs. Harrison and Cox and myself.

*Remarks.*—The species recalls *Omphalia conica* Zekeli of the Gosau beds in the style of nodular banding, but the Jamaican shell is larger and has the sides more concave towards the apex and the spire more tapering. *O. giebeli* Zekeli from Gosau is 100 mm. high, but is not ornamented with nodes. Cossmann places both these Gosau forms in the Turonian.

*Turritella* cf. *forgemolli* Coquand. (Pl. I, Fig. 4.)

A specimen consisting of the body whorl and two previous whorls 58 mm. high and 29 mm. in diameter was found by Mr. R. Cory near Catadupa and resembles figures by A. Quaas of this species from the highest Cretaceous of the Libyan desert (*Palaeontogr.*, Bd. xxx, Abt. ii, Lief iv, 1902, pl. xxv, figs. 38–40). In Algeria it occurs also in the Eocene (Suessonian). The whorls have a rounded ridge just below the suture below which the sides are concave and develop sharp spiral ridges that become strong just above the suture; the growth lines are sinuous and tend to form a reticulation on the sides but become foliacious on the base and near the aperture which seems to have a sharp detached rim.

*Turritella* (*Torcula*) cf. *overwegi* Quaas. (Pl. IV, Fig. 5.)

A thin shelled form, about 25 mm. long, having well sunken sutures, and three to five sharp spiral ridges varying in strength on different individuals, occurs in shales around Catadupa. It resembles figures of this species from the highest Cretaceous *Overwegi* beds of Egypt (*Palaeontogr.*, Bd. xxx, Abt. ii, Lief iv, 1902, pl. xxvi, figs. 13 and 14). A similar looking shell, *T. multistriata* Stol., also occurs in the Arrialoor group of India (*Cret. Fauna of S. India*, 1868, vol. ii, p. 228, pl. xvii, figs. 9–11).

*Turritella* aff. *cardenasensis* Böse. (Pl. IV, Figs. 14 and 15.)

1906. "La Fauna de Senoniano de Cardenas": *Boletin Instituto geol. Mexico*, No. 24, p. 62, pl. xiii, figs. 4–6, 10–13; pl. xiv, fig. 3.

*Description.*—Shell tapering, of 8 or 9 whorls, the sutures shallow, the sides of the whorls nearly flat, the surface having 7 or 8 flat bands separated by spiral incisions which vary in depth on different specimens, but are more strongly marked on the posterior part of each whorl than on the anterior. The body whorl has about 14 spiral grooves, the anterior five of which are stronger than the median ones. The inner lip is rather strongly calloused, the outer lip is missing.

*Dimensions.*—Length about 52 mm., diameter of body whorl 14 mm.

*Locality.*—About twenty specimens were collected in dark shales some 900 feet below the *Barrettia* limestone at St. Ann's Great River.

*Remarks.*—On the Mexican specimens the bands are more or less cut up into rectangular nodes by transverse incisions, but this feature is scarcely seen on the Jamaican specimens though the species seems very similar if not identical. In Mexico it occurs near Cardenas on a horizon with *Actaeonella* and *Corallio-chama G. Boehmi* said to be Lower Senonian.

*Vermetus* (or *Vermicularia*) cf. *libycus* Quaas. (Pl. IV, Fig. 33.)

Shell of six whorls, separated to the apex from one another, circular in section. The early shell seems to be plain, but later whorls bear numerous close-set rather irregularly sized and spaced faintly nodose spiral ridges with rounded furrows between them. The ridges on the base are more irregular in size than those on the sides. Length 24 mm., diameter of last whorl 16 mm. From shales above the *Barrettia* limestone at St. Ann's Great River. It seems very similar to *V. libycus* Quaas (*Palaeontogr.*, Bd. xxx, Abt. ii, Lief iv, 1902, pl. xxvi, fig. 22) from the highest Cretaceous of the Libyan desert.

*Cerithium* cf. *libycum* Wanner. (Pl. IV, Figs. 9 and 10.)

*Description.*—Shell of 22 or more whorls, slender, enlarging gradually, sides of the apical shell slightly concave, of the later shell straight. Suture very faint on the early whorls rather deeper on the later ones. Earlier whorls have three equidistant lines of small nodes, that just below the suture being rather more prominent than the others. On the later shell there is a line of larger rounded nodes below the suture, and below that two almost equidistant lines of smaller but equal sized nodes, and just above the suture a faint raised ridge. The columella has a small sharp anterior fold evidently corresponding to a channel in the aperture but the outer lip is missing. Length about 58 mm., diameter of body whorl 8 mm.

*Locality.*—In dark shales above the *Barrettia* limestone at St. Ann's Great River.

*Remarks.*—These specimens resemble figures of *C.* cf. *distinctum* Kaunhowen and *C. libycum* Wanner from the uppermost chalk of the Libyan desert (*Palaeontogr.*, Bd. xxx, Abt. ii, Lief iii, pl. xviii, figs. 33 and 34).

*Cerithium* cf. *dachelense* Wanner. (Pl. III, Fig. 20.)

A shell 59 mm. long was collected by Mr. R. Cory near Catadupa. It has about 13 whorls with the sutures fairly sunken and the sides of each whorl gently rounded. The last whorl has fourteen nearly upright varices, one of them much enlarged, crossed by numerous fine but variable spiral ridges. The outer lip is missing but the inner lip has a spreading callosity. It is not unlike, though rather larger than, the above species from the highest white chalk of the Libyan desert (*Palaeontogr.*, Bd. xxx, Abt. ii, Lief iii, 1902, p. 130, pl. xviii, figs. 25–8.)

### *Rostellaria* (*Calyptrophorus*) sp. (Pl. IV, Fig. 29.)

Poorly preserved specimens of a shell apparently referable to this genus occur above the *Barrettia* limestone at St. Ann's Great River. They are about 38 mm. long and 14 mm. wide, and may have some affinity with *C. septentrionalis* Stanton from the Cannonball marine member of the Lance formation of Dakota (Stanton and Vaughan, *U.S. Geol. Survey, Paper* 128A, 1920, p. 39, pl. vii, figs. 5–6).

### *Rostellaria* spp. (Pl. IV, Figs. 3, 11, and 36.)

Various *Alaria*- or *Rostellaria*-like shells, with the lips broken, occur in the Jamaican shales. A smooth form with elongate spire and very shallow sutures (Fig. 3) is rather common at Providence. Fig. 11 is from St. Ann's Great River below the *Barrettia* limestone, while a fragment of an ornate shell (Fig. 36) is from the Cambridge-Catadupa railway line.

### *Aporrhais* sp. (Pl. IV, Fig. 20.)

A small form occurs in the Providence shales and is 12 mm. high and 8 mm. wide. It consists of 5 or 6 whorls; the sutures are broad and deep, the fourth and fifth whorls are angulated below the middle, the body whorl has an angular ridge just above the middle and one or two less prominent ridges in front of it. The surface bears numerous fine rather sinuous oblique ribs crossed by fine spiral ridges. The lip expands outwards and also backwards towards the apex.

### *Aporrhais* sp. (Pl. II, Fig. 12.)

Shell of more than seven whorls, the apex missing, sutures well impressed. The early whorls are nearly smooth, the later ones are gently rounded and decorated with rather sinuous oblique low rounded ribs crossed by broad low spiral ridges. On the penultimate whorl a broad ridge appears rather below the middle and becomes stronger on the body whorl, the oblique ribs becoming very faint. The last whorl also has about 23 spiral ridges, of varying strength, which pass on to the labial expansion. The lip is damaged, but extends backwards towards the apex and forwards to a blunt point. The inner lip is rather sharp and partly detached from the body whorl. Height probably 90 mm., width about 67 mm. Collected by Mr. P. T. Cox in shales immediately above the *Barrettia* limestone at St. Ann's Great River.

### *Eocithara jamaicensis* sp. nov. (Pl. IV, Fig. 17.)

Shell of 4 or 5 whorls which enlarge rapidly, the last one being spacious and about twice as high as the spire, the sides gently rounded. The sutures are deep and the whorls tabulate below them. The body whorl has about 11 sharp prominent ribs extending from the suture to the anterior end which tend to become acute at the shoulder, the spaces between them are broadly hollowed and bear spiral ridges which are few and broad on the main part of the shell but become finer and closer set anteriorly. Length 21 mm., diameter of body whorl 13 mm. One specimen from Providence shales.

This shell rather resembles but is smaller than *E. mutica* Lam. from the Calcaire Grossier of Chaussy in the Paris area. These early Harp-like shells differ materially from the living genus *Harpa* and cannot be directly ancestral to the modern forms.

### *Murex* (?) sp. (Pl. IV, Fig. 4.)

A specimen from the Providence shales is a cast of three well-rounded whorls, the sutures are sunken, and the body and penultimate whorls each have about six irregularly spaced coarse varices which are bluntly spinose at the shoulder. Height 21 mm., diameter 15 mm.

### *Gosavia* sp: (Pl. III, Fig. 19.)

*Description.*—Shell rather thin, elongate, of about six whorls, the body whorl considerably longer than the spire which is rather elevated. The apex and the anterior end and outer lip are broken. The sutures are fairly sunken and the body whorl is decorated with 9 or 10 longitudinal ribs that start below the suture but die away anteriorly. These ribs and the furrows between them are crossed by eleven or twelve strong sharp spiral ridges which become oblique anteriorly. The aperture is elongate and the inner lip bears about six sharp oblique folds. Length 36 mm., diameter 20 mm.

*Locality.*—Dark shales above the *Barrettia* limestone at St. Ann's Great River.

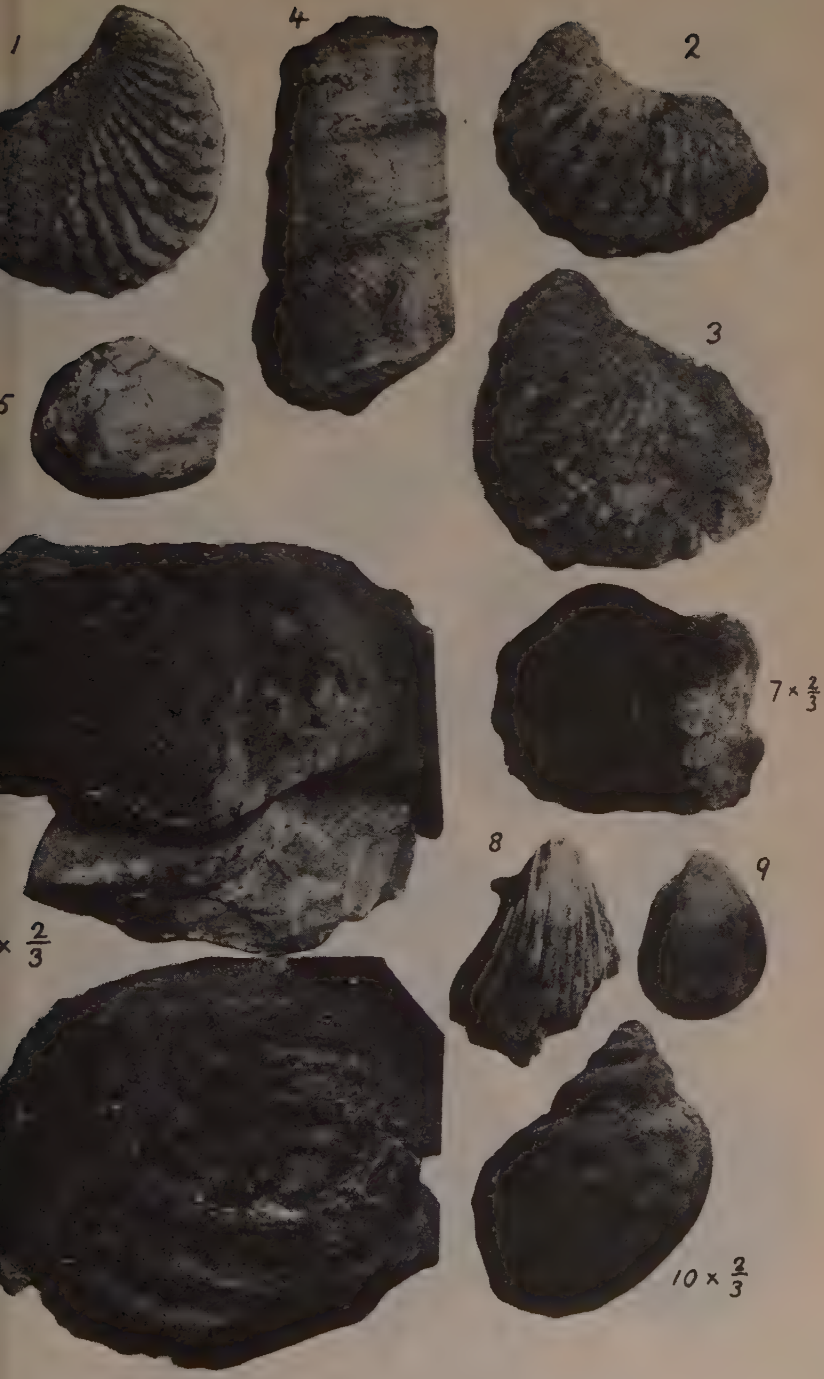
*Remarks.*—It has similar ornamentation to *Voluta elongata* d'Orb. (Zekeli, *Gasteropoden der Gosaugebilde*, pl. xiii, figs. 10*a* and *b*) but the spire in the Gosau shell is higher. It compares also with *Gosavia indica* Stol. (Cret. Fauna of S. India, *Pal. Ind.*, 1868, vol. ii, p. 73, pl. vi, figs. 7 and 8).

## EXPLANATION OF PLATES I–IV.

All specimens are represented natural size unless otherwise stated.

### PLATE I.

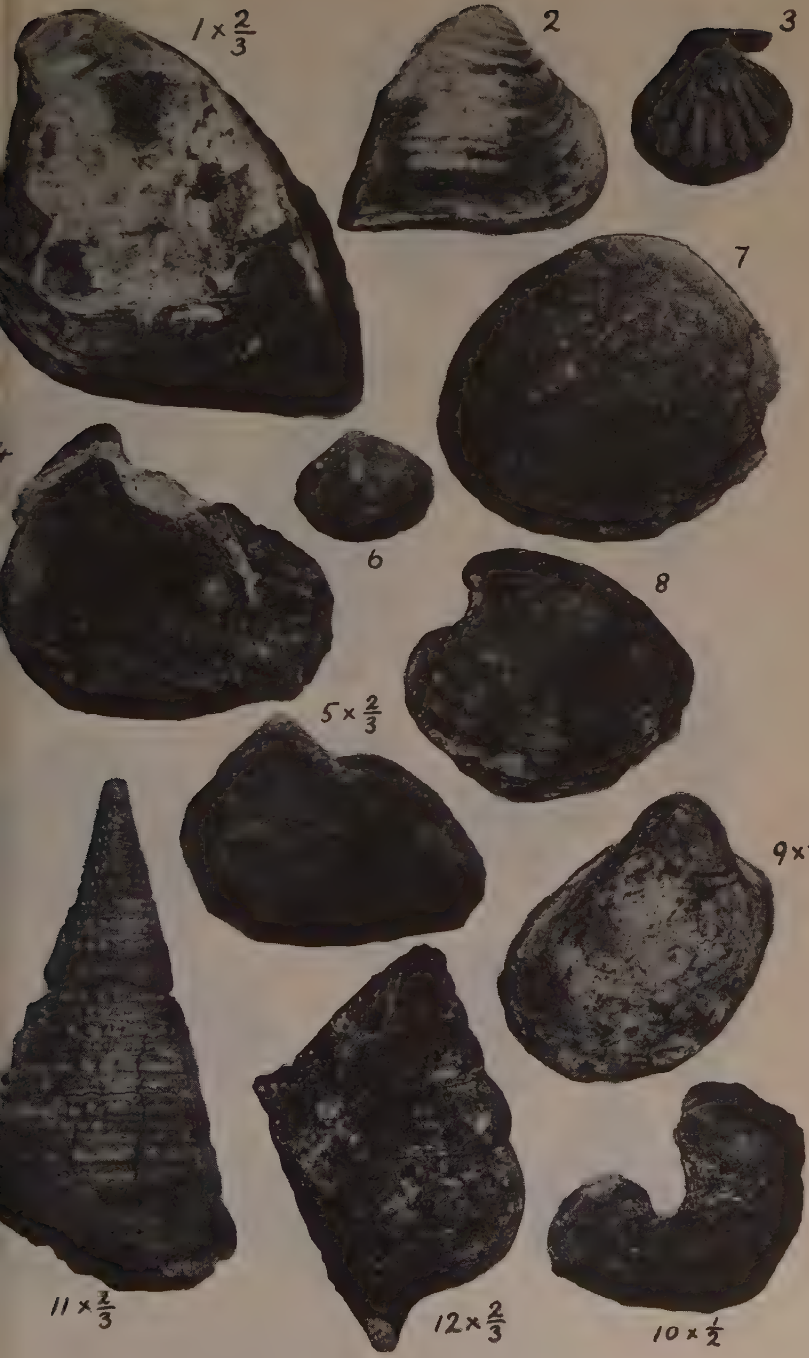
FIG.
1. *Trigonia emoryoides* sp. nov. Cambridge-Catadupa railway line.
2. Ditto, variety. Same locality.
3. Ditto, variety. Near Catadupa.
4. *Turritella* cf. *forgemolli* Coq. Near Catadupa.
5. *Tellina* (?) sp. Cambridge-Catadupa railway line.



*T. T., photo.*

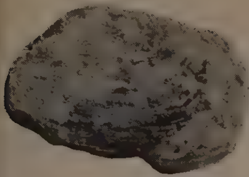
Cretaceous Shale Fossils, Jamaica.

[*To face p. 40.*



*C. T. T., photo.*

Cretaceous Shale Fossils, Jamaica.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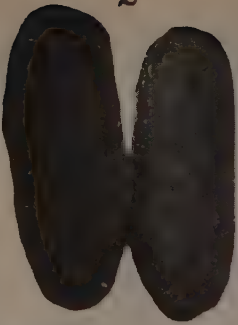
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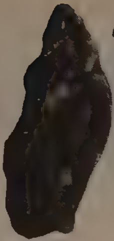
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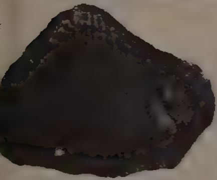

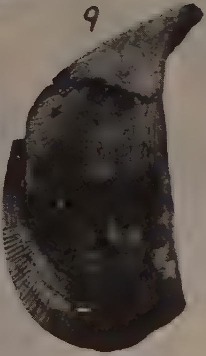
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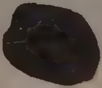
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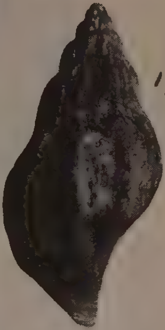
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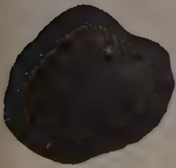

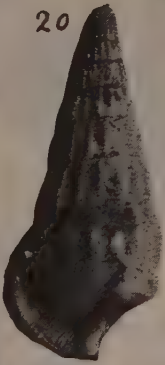
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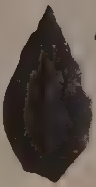
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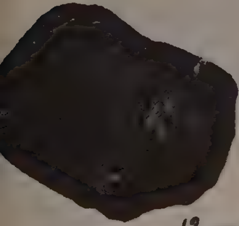

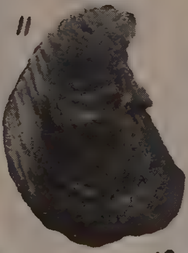
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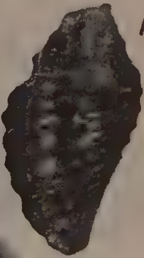
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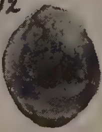
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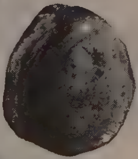
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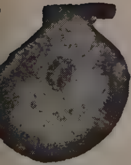

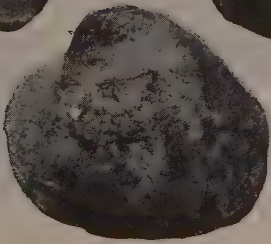
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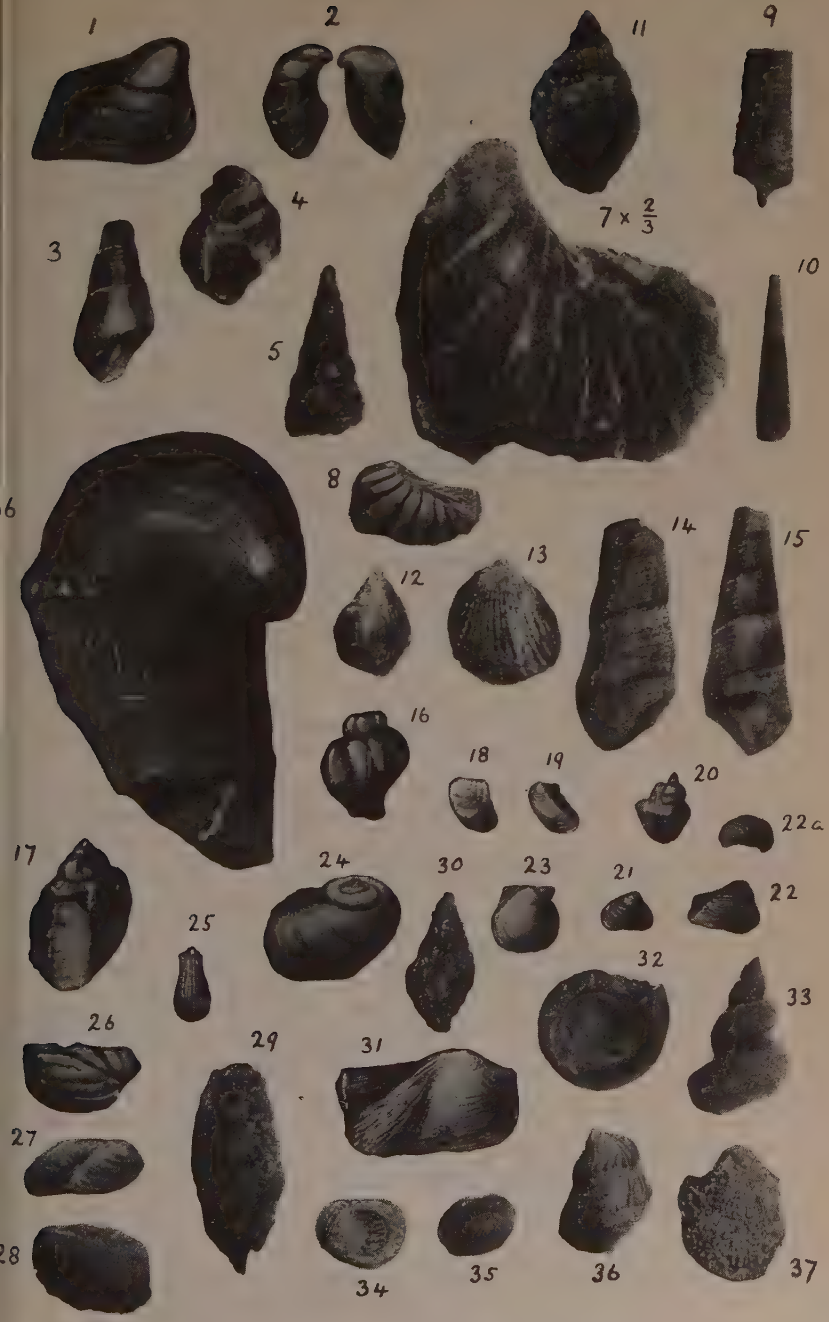
. T., *photo.*

CRETACEOUS SHALE FOSSILS, JAMAICA.



C. T T., photo et del.

Cretaceous Shale Fossils, Jamaica.

FIG.

6. *Inoceramus* cf. *balticus* Boehm. St. Ann's Great River, 1000 feet below the *Barrettia* limestone. Left and right valves, about two-thirds nat. size.
7. *Pholadomya tigroides* sp. nov. Providence shales, about two-thirds nat. size.
8. *Neithea quinquecostata* J. Sow. Cambridge-Catadupa railway line.
9. *Cardium* cf. *gosaviense* Zitt. Cambridge-Catadupa railway line.
10. *Amauropsis* cf. *altilirata* Böse. Cambridge-Catadupa railway line, about two-thirds nat. size.

PLATE II.

1. *Roudaireia jamaicensis* sp. nov. Cambridge-Catadupa railway line, about two-thirds nat. size.
2. Ditto, a young example. Near Catadupa.
3. *Pecten* cf. *septemplicatus* Nilsson. Providence shales.
4. *Cucullaea catadupensis* sp. nov. Cambridge-Catadupa railway cutting.
5. Ditto, same locality. A cast of two valves without the shell, about two-thirds nat. size.
6. *Cytherea* sp. St. Ann's Great River, above the *Barrettia* limestone.
7. *Cytherea catadupensis* sp. nov. Cambridge-Catadupa railway cutting.
8. *Thracia* (?) sp. Providence shales.
9. *Laevicardium* (?) sp. Cambridge-Catadupa railway cutting. One-half nat. size.
10. *Antillocaprina* (?) sp. Cambridge-Catadupa railway cutting. Right and left valves conjoined, about a half natural size.
11. *Glauconia matleyi* sp. nov. St. Ann's Great River, above the *Barrettia* limestone. About two-thirds nat. size.
12. *Aporrhais* sp. Same locality, about two-thirds nat. size.

PLATE III.

1. *Legumen* (?) sp. Cambridge-Catadupa railway cutting.
2. *Legumen* cf. *appresum* Conrad. Providence shales. Both valves conjoined.
3. Ditto. Cambridge-Catadupa railway cutting.
4. *Pholadomya jamaicensis* sp. nov. Providence shales.
5. Ditto, another specimen. Same locality.
6. Ditto, a third specimen. Same locality.
7. *Camptonectes* cf. *curvatus* Gein. Cambridge-Catadupa railway cutting.
8. Ditto. Providence shales.
9. *Septifer acutus* sp. nov. Cambridge-Catadupa railway cutting.
10. *Cardita* sp. Cambridge-Catadupa railway cutting.
11. *Ostrea* cf. *conica*. Cambridge-Catadupa railway cutting.
12. *Laevicardium* sp. Cambridge-Catadupa railway cutting.
13. Ditto, another specimen. Same locality.
14. *Pleuromya* (?) sp. Cambridge-Catadupa railway cutting.
15. *Terebratulina* (?) sp. Providence shales.
16. *Lyria* or *Volutilithes* sp., a cast. Providence shales.
17. *Lyria* sp. Near Catadupa.
18. *Lyria* cf. *crassicostata* Stol. St. Ann's Great River, above the *Barrettia* limestone.
19. *Gosavia* sp. St. Ann's Great River, above the *Barrettia* limestone.
20. *Cerithium* cf. *dachelense* Wanner. Near Catadupa.

PLATE IV.

1. *Veniella* sp. Providence shales.
2. Ditto. Same locality. Sketch of front view of two valves in apposition.
3. *Rostellaria* sp. Providence shales.

FIG.
4. *Murex* (?) sp. Providence shales.
5. *Turritella* cf. *overwegi* Quaas. Cambridge-Catadupa railway cutting.
6. *Antillocaprina* (?) sp. Cambridge-Catadupa railway cutting. A crushed specimen showing both valves.
7. *Trigonia* sp. Providence shales, a cast about two-thirds natural size.
8. *Trigonia* cf. *cerulea* Whitfield. Providence shales. a fragment.
9. *Cerithium* cf. *libycum* Wanner. St. Ann's Great River, above the *Barrettia* limestone.
10. Ditto, same locality. Spiral fragment of another specimen
11. *Rostellaria* sp. St. Ann's Great River, below the *Barrettia* limestone.
12. *Lunatia* cf. *larteti* Böhm. St. Ann's Great River, below the *Barrettia* limestone.
13. *Cardium* (*Fragum* ?) sp. Near Catadupa.
14. *Turritella* aff. *cardenasensis* Böse. St. Ann's Great River, below the *Barrettia* limestone.
15. Ditto, same locality. Another specimen.
16. *Fusus* (?) sp. Providence shales.
17. *Eocithara jamaicensis* sp. nov. Providence shales.
18. *Avicula* sp. Providence Shales.
19. Ditto, same locality. Another specimen.
20. *Aporrhais* sp. Providence shales.
21. *Corbula* cf. *parsura* Stol. St. Ann's Great River, below the *Barrettia* limestone. A left valve.
22. Ditto, same locality. A right valve.
22*a*. Ditto, same locality. Front view of a right valve.
23. *Amusium* (?) cf. *membranaceum* Nilsson. St. Ann's Great River, above the *Barrettia* limestone.
24. *Ampullina* sp. Providence shales.
25. *Neithea* sp. St. Ann's Great River, above the *Barrettia* limestone.
26. *Gryphaea* cf. *hypoptera* Wanner. Providence shales.
27. *Modiolaria catadupensis* sp. nov. Cambridge-Catadupa railway cutting.
28. *Modiolaria* sp. Cambridge-Catadupa railway cutting.
29. *Calyptrophorus* sp. St. Ann's Great River, above the *Barrettia* limestone.
30. *Volutilithes* sp. St. Ann's Great River, below the *Barrettia* limestone.
31. *Barbatia* sp. Providence shales.
32. *Solarium* sp., umbilical view. St. Ann's Great River, above the *Barrettia* limestone.
33. *Vermetus* cf. *libycus* Quaas. St. Ann's Great River, above the *Barrettia* limestone.
34. *Nerita subcompacta* sp. nov. St. Ann's Great River, below the *Barrettia* limestone.
35. Ditto, same locality. Another specimen.
36. *Rostellaria* sp. Cambridge-Catadupa railway cutting.
37. *Plicatula* cf. *andersoni* Newton. St. Ann's Great River, above the *Barrettia* limestone.

*(To be continued.)*

# REVIEWS.

SUMMARY OF PROGRESS OF THE GEOLOGICAL SURVEY OF GREAT BRITAIN FOR 1925. pp. vi + 211, with 12 plates and 24 text-figures. 1926. Price 4*s.* 6*d.*

THIS publication gives evidence of the existence of great activity in the Geological Survey. It contains a large number of extremely interesting reports from the various districts and on the general work of the Survey, together with eight special appendices. Among so much rich material for comment, where selection is somewhat invidious, we may perhaps start harmlessly by saying that the twelve plates are very beautiful specimens of geological photography, of high technical excellence.

The Report of the Director begins with a graceful reference to the death of Mr. William Whitaker and the retirement of Dr. Walcot Gibson, and then goes on to chronicle the results of a visit on his own part to a number of continental museums in preparation for the designing of new headquarters for the Survey, in place of the present museum in Jermyn Street, whose decrepit condition is the subject of pathetic references in several parts of the Summary.

There is also an interesting chapter dealing with the history of geological maps, tracing the evolution of the different types published by the Survey.

In the Districts the main strength of the personnel has been concentrated in the coalfields, and many new maps and memoirs are now in preparation or already published, the last category including a very important publication on the concealed coalfield of the Don-Trent area, to coin a new term somewhat less cumbrous than the accepted one.

Around London and in the Midland District, in Yorkshire, Lancashire, Cumberland, Northumberland, and Durham and in three areas in Scotland, much active work has been carried on and great progress made with revision of the old maps. An important memoir on North Cumberland has recently been reviewed at length in these pages.

It is also specially noted that the publication of vertical sections has been resumed ; two sheets in the concealed coalfield of Yorks and Notts show in detail, colour-printed, all the principal sinkings and borings : these should be extremely useful.

Reference may also be made to the completion of the first volume of the late Dr. Kidston's great work on the fossil plants of the Carboniferous. The hope is expressed that in time the whole will be published, although there will be inevitable delay. Meanwhile the Kidston Collection has been received and made accessible at Jermyn Street.

In the petrographical section some intriguing notes, due to Dr. Thomas, give a sketch of the Tertiary igneous rocks of Ardnamurchan, as to which we hope to hear much more in the future, and in the chemical department were made a number of extraordinarily and perhaps unnecessarily complete analyses of rocks, mainly for Scottish regional memoirs. A large number of constituents are returned as amounting to 0·00 per cent; in twenty-one analyses given this figure recurs 69 times, and in numerous other cases the merest trace was found; and it is an open question whether the time involved in the search for Ba, Co, Ni, Li, and so on, is worth while, except in special and usually obvious circumstances.

The appendices to the Summaries of Progress are always awaited with interest by British geologists, as they frequently contain pearls of great price to workers in various branches, and one of their most useful features is the good accounts there often to be found of borings and sinkings for various purposes. This year we have an account of the new tunnel through the Malvern Hills, parallel to the old single-line one at Colwall, with a most careful description by Dr. Robertson; a bore-hole in the Jurassic at Wincanton, Somerset; two new shafts at Annfield Plain, Durham; an admirable description of the basalt of Little Wenstock, which Mr. Pocock shows clearly to be a contemporaneous flow, and not an intrusion; an instructive discussion of the thicknesses of the Permian in Yorkshire and Notts, by Mr. Wilson, besides two palaeontological papers by Professor Hawkins and Mr. W. B. Wright.

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UGANDA PROTECTORATE. Ann. Rep. Geol. Surv. Depart. for 1925. pp. 30, Geol. Sketch Map, scale 1 : 2,000,000. Entebbe, 1926.

THIS comprehensive Report deals with the many sides of the work of the Geological Survey under the Directorship of Mr. W. J. Wayland and only points of general interest will be touched upon in this short notice. Brief details of a reconnaissance by the Director of the relatively little known northern parts of the Protectorate and Karamoja are given; the various granites, some containing sphene and zircon, the wide distribution of charnockite, the first found intrusive olivine-dolerite, and the promising nature of the ground, differing somewhat from other parts of Uganda, for economic investigation, are all points of interest. From a general summary of field work carried out in 1925 (A. D. Combes) we learn that the Ankolian Series of Uganda, formerly the Argillite Series, and the Karagwe Series of Karagwe are now found to be the same, the beds covering an area of at least 5,000 square miles, and locally, when metamorphosed containing cassiterite. An examination of the volcanic area of Bufumbiro, N.E. of Lake Kivu, showed characteristically basic rocks, with now and again a noticeable quantity of leucite. The only other instance the writer can remember of the occurrence of this mineral in East African volcanics is that recorded by Professor Gregory in a tephrite from the Magadi District.

An interesting point is the information concerning the Bukoba Sandstones of post-Ankolian Karagwe age and possibly belonging to the Mitayana-Butologo Series which forms the S.W. shore of Lake Victoria. They have a thickness of several thousand feet, so far not more precisely determined.

The Geology of Uganda progresses and not the least interesting point in its progression is the differentiation (the likenesses are not forgotten) from Kenya Colony and the alliance, as shown by the presence of thick masses of old unfossiliferous sediments, with the lands to the south.

J. P.

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NYASALAND PROTECTORATE. Ann. Rep. Geol. Surv. Depart. for 1925. F. DIXEY, Government Geologist. pp. 7. Zomba, 1926.

IN this Report brief mention is made of the coal areas of Sumbu and Chiromo, fuller accounts of both being either published or shortly to be expected, and the interesting bauxite deposits of the Mlanje Mountains, compared by Dr. Dixey with those of the Gold Coast. He estimates moderately 20,000,000 tons with an alumina content of about 57½ per cent.

Cement materials, clay products and water supply are touched on, and mention made of some reptilian remains, occurring in a down-faulted strip of Karroo beds, the discovery being of interest from the point of view of correlation as well as palaeontology. The dinosaur beds overlie these with strong unconformity, and on these again, also with strong unconformity, are found the post-Cretaceous lacustrine deposits of North Nyasa

J. P.

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# REPORTS AND PROCEEDINGS.

## EDINBURGH GEOLOGICAL SOCIETY.

17*th March*, 1926.

1. "On the Occurrence of Petroliferous Sandstones in the Carboniferous Rocks of Scotland and their Relationship to certain Black Sandstones." By D. Tait, H.M. Geological Survey.

Mr. Tait first dealt with the occurrence of petroliferous sandstones in the Carboniferous rocks of Scotland. Traces of oil so small in quantity as to have no commercial value occur frequently in the sandstones at many different levels. Oily sandstones have been noted in Fifeshire, Midlothian, and Lanarkshire. They were mostly recorded in the cores of bores put down in search of coal. In one borehole oil was noted in sandstones at no less than seven different levels. These records occur in the geological subdivisions known as the Millstone Grit, Upper Limestone Group, Limestone Coal Group, and

Calciferous Sandstone Series. The second part of the paper dealt with certain black sandstones which are found near igneous intrusions It was pointed out that oil contained in sandstones must frequently have been burnt by the heat of igneous rock injected among the sedimentary strata. Where that had taken place, a black sooty residue from the burnt oil was deposited in the pores of the sandstone. This material gives these sandstones their black colour.

2. "Notes on the Extrusive Igneous Rocks of the Dundee District." By John W. Harris, B.Sc., the Geology Department, University of St. Andrews.

On the north side of the River Tay the Old Red Sandstone lava-form rocks are essentially andesites, many of which carry hypersthene, while some are poor in ferromagnesians. Thin veins of ash and fine sediment are frequently found in the lavas, while two bands of andesitic agglomerate occur. The lavas are found to vary greatly in the direction of flow, a feature which has been noted in other Old Red Sandstone igneous centres of Scotland. Typically acid types, such as dacites, are wanting, and it is probable that many of the lavas belong to early phases of Lower Old Red Sandstone volcanic activity.

3. "Notes on the Geology of the Country about Kidlaw, East Lothian." By John B. Simpson, B.Sc., H.M. Geological Survey.

This paper is summarized under the following heads :—

(*a*) An exposure of volcanic ash in the road-metal quarry at Kidlaw Farm, and the contact of the ash and basalt ; the section now exposed indicates that the basalt most probably is a plug in a vent, and certainly does not represent a sill, as was formerly supposed.

(*b*) A small lenticular granite boss, three hundred yards south-east of Kidlaw Farm ; this mass, hitherto unrecorded, is intruded into strata of Ordovician age. It belongs to the suite of Lower Old Red Sandstone intrusions.

(*c*) An occurrence of cherts of Arenig age, previously unmapped, beside Lammer Loch, half a mile south of Kidlaw Farm.

4. Exhibits.

Mr. James Lunn, B.Sc., exhibited amethystine quartz from Kaimes Quarry, West Lothian, and Mr. A. M. Cockburn, B.Sc., showed various specimens of Canadian ores.

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## GEOLOGISTS' ASSOCIATION.

*2nd July*, 1926.

"Orford Ness : A Study in Coastal Physiography." By J. A. Steers, M.A., F.G.S.

This paper deals with the great shingle spit deflecting the River Alde in Suffolk.

The general structure of the spit is described in some detail, and its relation to the East Anglian coast in general is also considered.

The history of the growth of the spit can be traced in some detail from a study of various records and maps of this part of the Suffolk coast. The present features of this spit enable its evolution to be studied fully, and also throw some light on the nature and action of the forces to which it owes its being.

It is comparable to such shingle accumulations as Dungeness, Cape Carneveral in America, and the Darss in Germany. Following modern terminology, it may be called a complex cuspate foreland.

"On Sandstones with Breccias below the Trias in South Warwickshire." By L. Richardson, F.R.S.E., F.G.S., and W. F. Fleet, M.Sc., A.I.C., F.G.S.

The paper describes beds pierced by a recent boring at Stratford-on-Avon. Such include Keuper Marl and "Passage-beds" (466¼ ft.), and Lower Keuper Sandstone (152¾ ft.), underlain by sandstones with thin breccia-bands, ? Upper Coal Measures (Enville Group), and penetrated for 53¼ ft. The latter resemble the Enville Breccia rocks of Shropshire and Staffordshire. Efforts to obtain information regarding the presence or absence of similar beds in South Warwickshire are described, and an account of the petrology of the Stratford cores is followed by details of sandstones and breccias found by the authors at Kenilworth.

The relationships of the Stratford and Kenilworth rocks are discussed, and a description is given of further investigations near Warwick and Leamington, with evidence for the occurrence of breccia in a boring at Tachbrook Mallory.

It is concluded that although thick and coarse scree-material is not present in South Warwickshire, there is evidence of a phase of breccia-deposition generally comparable with that which took place at Enville and Clent.

"Glacial Tectonics as reflected in Disturbed Drift Deposits." Part I: Preliminary Considerations. By George Slater, D.Sc.

I. Historical Retrospect.—The history of the investigation of glacial phenomena is briefly described.

The mapping of Drift Deposits proved that there was a close analogy between Alpine Glacial phenomena and the Drift Deposits in other mountain areas.

Analogies between lowland Drift Deposits and Arctic Glacial phenomena are also close, whether on a local or regional scale. The present investigation deals with local analogies as shown by the tectonic structure of disturbed Drift Deposits.

II. A New Conception of Disturbed Drift Deposits.—Prolonged investigations of disturbed East Anglian Drift Deposits has led to the following conclusions :—

1. Glacial disturbances are local and superficial.

2. Lenticles of material have been incorporated as englacial deposits, transported, and remoulded on " cores " of " drumloid " form, assuming a definite tectonic structure.

3. The tectonic structure has been preserved, and the beds have maintained their relative positions owing to an extremely slow rate of melting of the interstitial ice.

4. Hence the beds as now seen represent a glacial " pseudomorph " or " fossil glacier ", the " hard parts " only remaining.

Analogous structure on a much greater scale has been investigated in America and Denmark. The structure has also been demonstrated experimentally by Professor W. J. Sollas, F.R.S. This type of investigation promises to lay the foundations of a new branch of geophysics by the combined labours of geologists in the field and physicists in the laboratory, as " Englacial material is analogous to the coloured material used by physicists to demonstrate in experimental physics the flow of viscous bodies ". (Prof. A. N. Whitehead, F.R.S.)

# CORRESPONDENCE.

## THE VARVED TERTIARY SEDIMENTS OF BURMA.

Sir,—I am indebted to Dr. Ernst Antevs, of Harvard University, for calling my attention to the applicability of the adjective " varved " to the sediments showing seasonal rhythm described in my paper " Seasonal Rhythm in the Tertiary Sediments of Burma ", Geological Magazine, November, 1925. De Geer proposed the word " varve " in 1912 as an international term for the distinctly marked annual deposit of a sediment regardless of its origin. The adjective " varved " has been used by Schuchert and the term " varvity " meaning " year-stratification " has been proposed by Kittredge. An important study of varved glacial sediments has been made by Antevs in his " Retreat of the Last Ice-Sheet in Eastern Canada ", *Canadian Geol. Surv.*, 1925. In view of the common occurrence of such banded sediments the term is a useful one.

L. Dudley Stamp.

University of London.
*10th October, 1926.*